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# Terrestrial Ecological Risk Assessment Army Materials Technology Laboratory





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August 1995

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*Prepared for:*

U.S. Army Environmental Center
Aberdeen Proving Ground
Maryland 21010-5401

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# TERRESTRIAL ECOLOGICAL RISK ASSESSMENT

# ARMY MATERIALS TECHNOLOGY LABORATORY

# FINAL

Document # SSIM-AEC-BC-CR-95071

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August 1995

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# TERRESTRIAL ECOLOGICAL RISK ASSESSMENT

## 1.0 INTRODUCTION

The objectives of this ecological risk assessment are to identify and estimate the potential terrestrial ecological impacts associated with the chemicals of potential concern detected in soils at the U.S. Army Materials Technology Laboratory (AMTL) Site in Watertown, Massachusetts. The assessment focuses on the potential for exposure and impact to terrestrial fauna that inhabit or are potential inhabitants of the site. The location of the site and surrounding vicinity is shown in Figure 1-1.

The technical guidance for performance of the ecological risk assessment comes primarily from the following sources: *Ecological Risk Assessment* (EPA, 1986), *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference* (EPA, 1989a), *Risk Assessment Guidance for Superfund — Volume II, Environmental Evaluation Manual* (EPA, 1989b), *Summary Report on Issues in Ecological Risk Assessment* (EPA, 1991a), *Guidance for Disposal Site Risk Characterization in Support of the Massachusetts Contingency Plan* (MDEP, 1994), *Framework for Ecological Risk Assessment* (EPA, 1992a), and *Wildlife Exposure Factors Handbook* (EPA, 1993). Numerous other information sources were used to assist in this report preparation and are included in the references section.

The subsections that follow provide the objectives, approach, and results of the evaluation of potential ecological impacts associated with chemicals of potential concern at the AMTL Site.

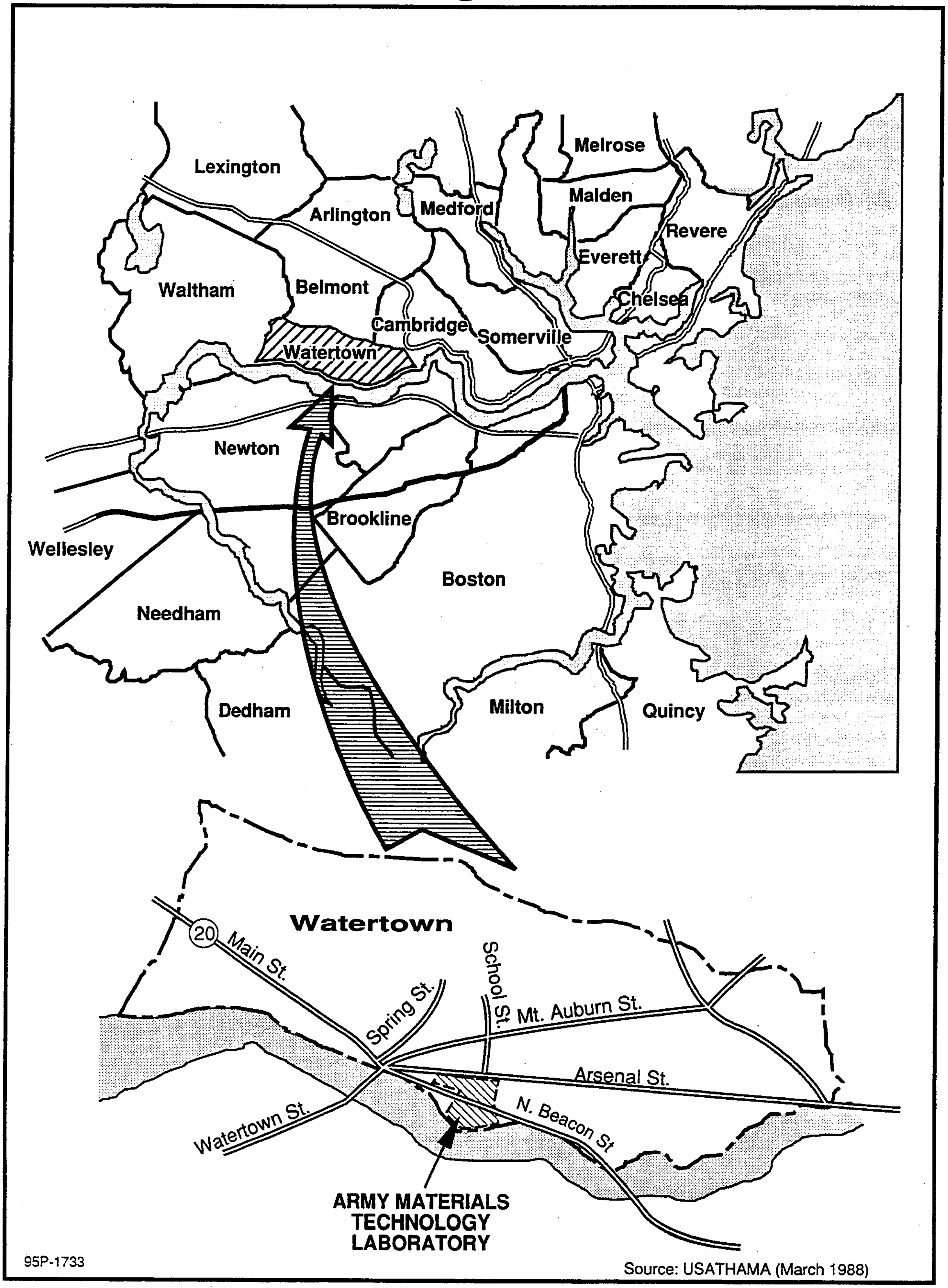



**FIGURE 1-1 SITE LOCATION MAP**

## 2.0 DATA EVALUATION AND REDUCTION

### 2.1 Approach

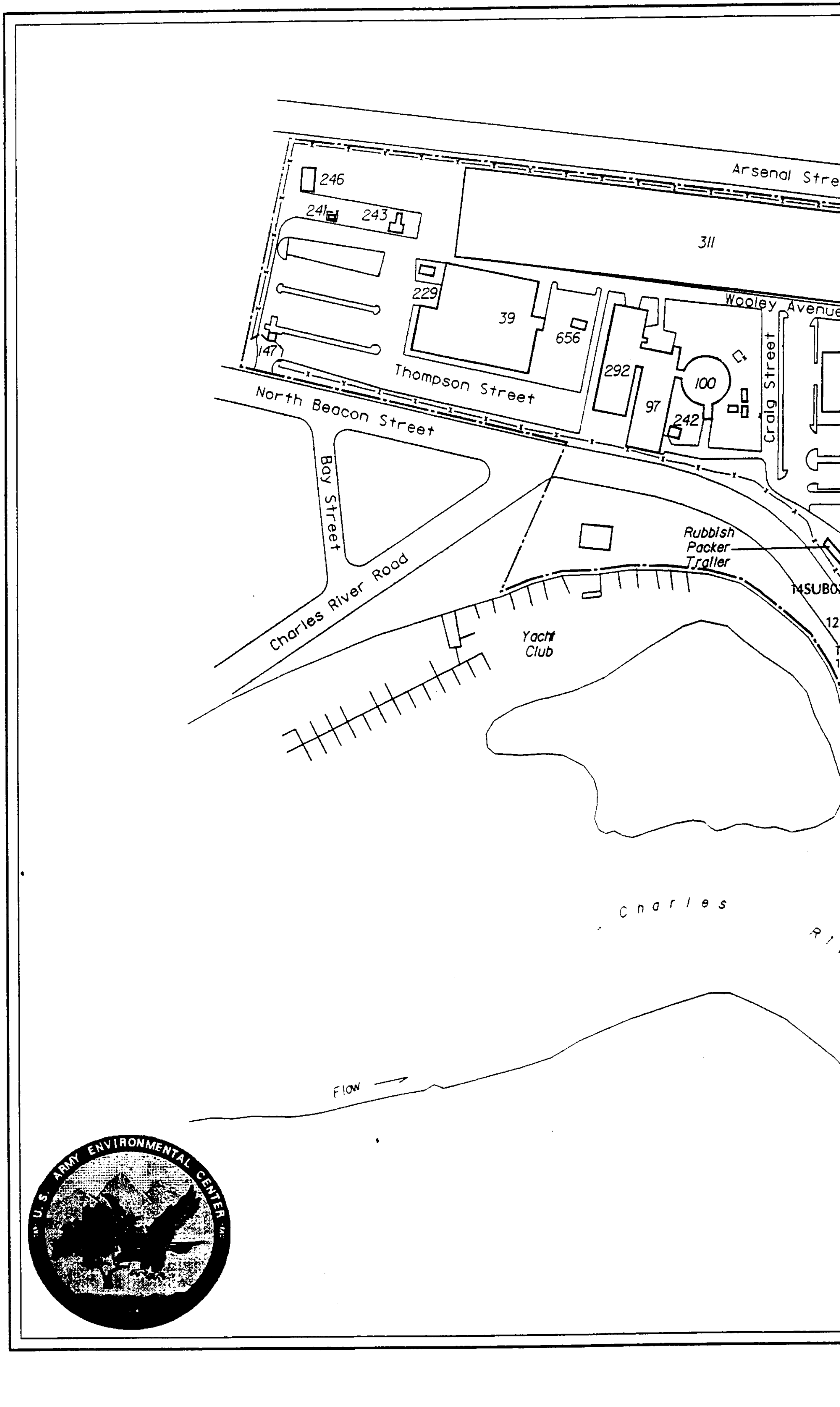
The objectives of the data evaluation and reduction are to review and summarize the analytical data for soils, and to select the chemicals of potential concern to be evaluated in the ecological risk assessment. The soils data used in this assessment were collected from a 0-2 foot interval during the Phase I (WESTON, 1991) and Phase II (WESTON, 1994) remedial investigations at the site, and represent 36 locations in the park and in the open space area in the vicinity of the Commander's Quarters. The soil sampling locations are shown in Figure 2-1. Soils data from the 0 to 2 foot interval were used, since these are the soils that ecological receptors are most likely to come into contact with.

The chemicals analyzed in soils included volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides/polychlorinated biphenyls (PCBs), and inorganics. Every sample location was not analyzed for all of the parameters. In general, inorganics were analyzed for at every location (except one Phase I sample where only pesticides were analyzed), and other parameters were analyzed at various locations based on historical knowledge and land use of the site.

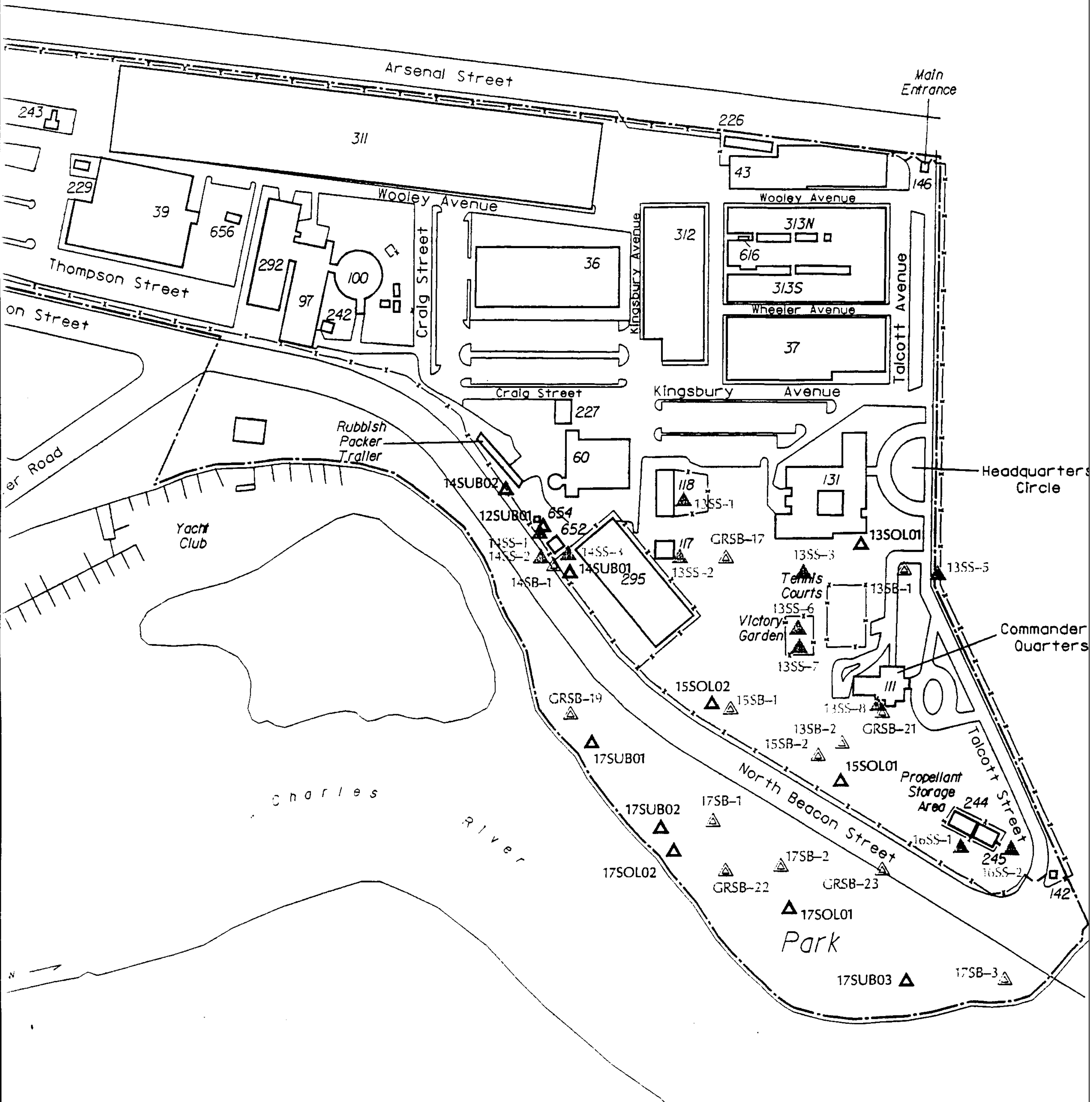
### 2.2 Data Summary and Reduction

A data summary for the positively identified compounds in soils are presented in Table 2-1. The summary table includes the following information:

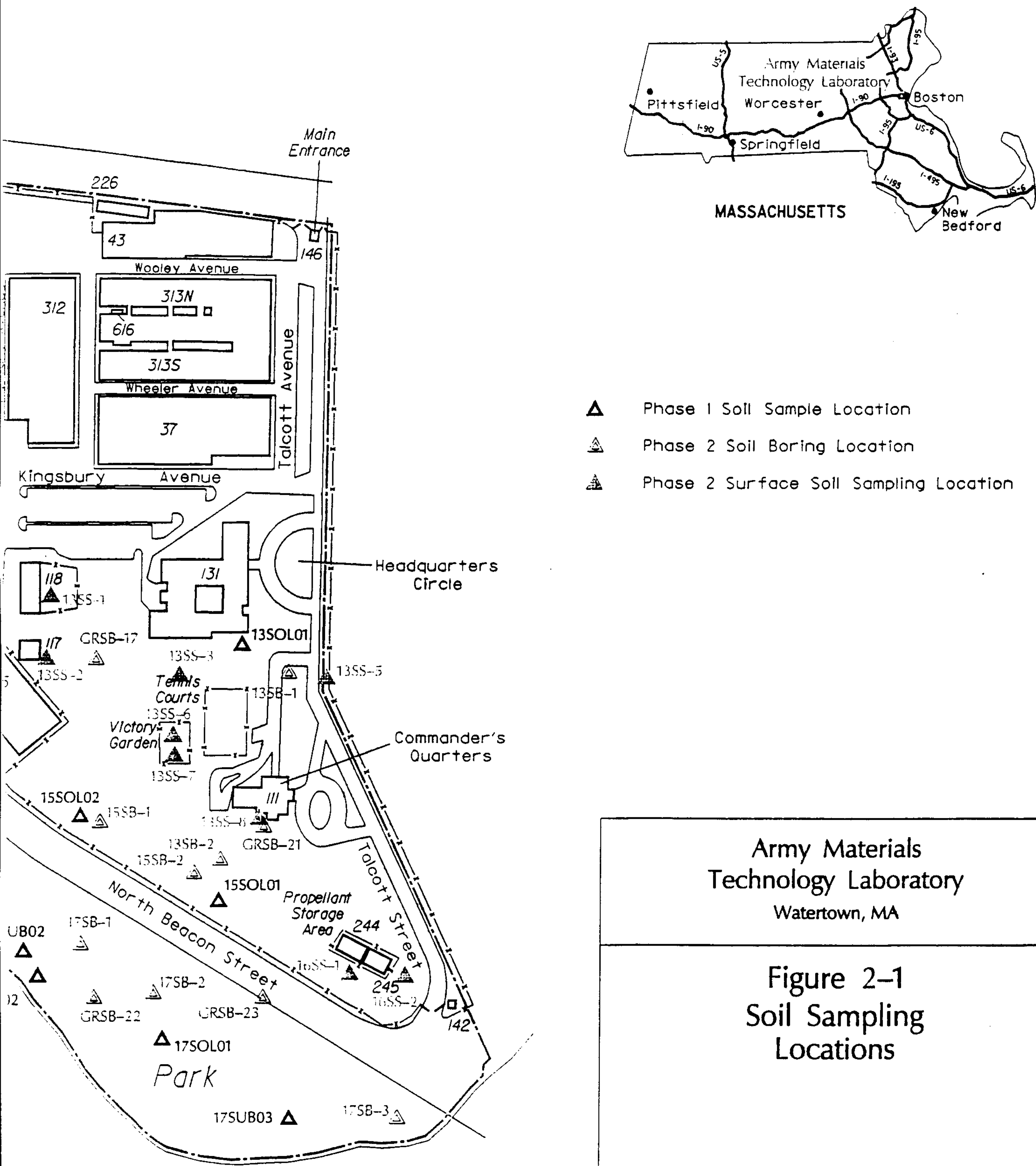
- The range of detected values.
- The frequency of detection and total number of samples analyzed.
- The range of quantitation limits.
- The arithmetic mean concentration.



Arsenal Stre
311
246
241
243
229
39
656
292
97
100
242
Wooley Avenue
Craig Street
147
Thompson Street
North Beacon Street
Bay Street
Charles River Road
Rubbish
Packer
Trailer
14SUB02
12S
Yacht
Club
Charles
Ri
Flow
U.S. ARMY ENVIRONMENTAL CENTER



Arsenal Street
Main Entrance
Wooley Avenue
Thompson Street
Craig Street
Kingsbury Avenue
Wheeler Avenue
Talcott Avenue
Kingsbury Avenue
Rubbish Packer Trailer
Yacht Club
Headquarters Circle
Tennis Courts
Victory Garden
Commander Quarters
Propellant Storage Area
North Beacon Street
Talcott Street
Charles River
Park
14SUB02
12SUB01
14SUB01
13SOL01
15SOL02
17SUB01
15SOL01
17SUB02
17SOL02
17SOL01
17SUB03
GRSB-17
GRSB-19
GRSB-21
GRSB-22
GRSB-23




Army Materials Technology Laboratory
Watertown, MA

Figure 2–1
Soil Sampling Locations

Scale
0 meters 150
0 feet 500

N

27–MAR–1995

WESTON

# Table 2-1

## Chemicals Identified in Soils (0-2 feet)

| Chemical | Range of Hits (mg/kg) | Frequency of Detection | Range of Quantitation Limits (mg/kg) | Arithmetic Mean (mg/kg) | Upper 95% Confidence Limit (mg/kg) |
|---|---|---|---|---|---|
| **Organics** | | | | | |
| Acenaphthene | 8.40E-02 - 4.79E-01 | 7 / 28 | 4.10E-02 - 4.10E+00 | 4.10E-01 | 1.37E+00 |
| Acenaphthylene | 1.63E-01 - 4.19E+00 | 9 / 28 | 3.30E-02 - 4.60E+00 | 6.32E-01 | 3.06E+00 |
| Acetone | 1.20E-02 - 5.10E-02 | 5 / 23 | 1.10E-02 - 3.30E+00 | 9.38E-01 | 9.31E+01 |
| Aldrin | 6.39E-03 - 7.62E-03 | 2 / 34 | 1.40E-03 - 1.30E+00 | 1.36E-01 | 1.21E+00 |
| Alpha-Chlordane | 5.00E-03 - 1.55E-01 | 9 / 11 | 2.00E-03 - 2.00E-03 | 3.15E-02 | 3.74E-01 |
| Alpha-Endosulfan | 2.48E-03 - 1.42E-02 | 4 / 33 | 1.00E-03 - 1.00E+00 | 1.07E-01 | 4.12E+00 |
| Anthracene | 1.59E+00 - 1.45E+01 | 4 / 28 | 5.40E-01 - 5.40E+00 | 1.39E+00 | 1.80E+00 |
| Benzene | 2.58E-01 - 2.58E-01 | 1 / 23 | 3.00E-03 - 1.00E-01 | 3.80E-02 | 2.97E-01 |
| Benzo (a) anthracene | 2.14E-01 - 3.15E+01 | 21 / 28 | 4.10E-02 - 3.00E+00 | 2.33E+00 | 7.83E+00 |
| Benzo (a) pyrene | 8.27E-01 - 3.66E+01 | 6 / 28 | 3.80E-01 - 3.80E+00 | 2.62E+00 | 3.63E+00 |
| Benzo (b) fluoranthene | 7.13E-01 - 1.54E+01 | 12 / 28 | 3.10E-01 - 3.60E+00 | 1.72E+00 | 3.94E+00 |
| Benzo (g,h,i) perylene | 3.78E-01 - 1.36E+01 | 13 / 28 | 1.80E-01 - 2.40E+00 | 1.53E+00 | 4.44E+00 |
| Benzo (k) fluoranthene | 4.06E-01 - 2.36E+01 | 15 / 28 | 1.30E-01 - 8.00E+00 | 2.30E+00 | 6.06E+00 |
| Benzyl alcohol | 1.29E+00 - 1.29E+00 | 1 / 28 | 3.20E-02 - 3.00E+00 | 3.05E-01 | 9.54E-01 |
| Beta-Endosulfan | 9.12E-04 - 1.31E-02 | 6 / 33 | 7.00E-04 - 2.40E+00 | 5.77E-01 | 1.43E+02 |
| Butanone, 2- | 1.80E-02 - 1.80E-02 | 1 / 24 | 1.00E-02 - 4.30E+00 | 1.17E+00 | 4.23E+02 |
| Butylbenzyl phthalate | 4.76E-01 - 1.10E+00 | 3 / 29 | 3.00E-01 - 3.00E+00 | 9.20E-01 | 1.23E+00 |
| Chlordane | 3.24E-01 - 9.36E+00 | 16 / 33 | 6.84E-02 - 3.00E+01 | 1.67E+00 | 5.64E+00 |
| Chrysene | 7.59E-02 - 3.39E+01 | 16 / 28 | 3.20E-02 - 4.50E+00 | 2.36E+00 | 1.31E+01 |
| DDD | 4.20E-03 - 3.48E+00 | 16 / 34 | 2.70E-03 - 6.40E-02 | 2.41E-01 | 8.19E-01 |
| DDE | 4.48E-03 - 6.33E+00 | 26 / 34 | 2.70E-03 - 6.80E-02 | 5.16E-01 | 2.57E+00 |
| DDT | 1.01E-02 - 5.20E+00 | 17 / 33 | 3.50E-03 - 4.10E+00 | 8.01E-01 | 4.61E+00 |
| Delta-Hexachlorocyclohexane | 2.01E-02 - 3.36E-02 | 3 / 34 | 5.00E-03 - 2.10E-01 | 2.27E-02 | 4.18E-02 |
| Dibenz (a,h) anthracene | 4.68E-01 - 3.34E+00 | 3 / 28 | 2.00E-01 - 2.00E+00 | 3.75E-01 | 4.65E-01 |
| Dieldrin | 7.00E-03 - 3.12E-01 | 14 / 34 | 1.60E-03 - 7.90E-02 | 3.43E-02 | 9.67E-02 |
| Endrin | 1.30E-02 - 5.00E-01 | 11 / 34 | 6.50E-03 - 1.30E+00 | 2.70E-01 | 4.96E+00 |
| Fluoranthene | 1.32E-01 - 5.41E+01 | 21 / 28 | 5.20E-01 - 5.20E+00 | 3.57E+00 | 5.55E+00 |
| Fluorene | 1.59E-01 - 1.05E+00 | 7 / 28 | 6.50E-02 - 3.00E+00 | 3.93E-01 | 1.05E+00 |
| Gamma-Chlordane | 1.40E-02 - 1.73E-01 | 6 / 11 | 4.00E-03 - 4.00E-03 | 3.08E-02 | 4.92E-01 |
| Heptachlor | 1.30E-02 - 1.30E-02 | 1 / 34 | 1.00E-03 - 2.40E-01 | 2.98E-02 | 1.56E-01 |
| Heptachlor epoxide | 2.28E-03 - 1.19E-01 | 13 / 34 | 1.30E-03 - 4.80E-01 | 5.94E-02 | 3.46E-01 |
| Indeno (1,2,3-cd) pyrene | 3.22E-01 - 1.04E+01 | 5 / 28 | 2.10E-01 - 2.40E+00 | 1.87E+00 | 4.09E+00 |
| Isodrin | 3.10E-02 - 3.43E-01 | 6 / 34 | 3.00E-03 - 4.80E-01 | 6.64E-02 | 4.01E-01 |
| Methoxychlor | 5.09E-02 - 4.70E-01 | 4 / 33 | 3.59E-02 - 1.00E+01 | 7.54E-01 | 2.68E+00 |
| Methylnaphthalene, 2- | 6.41E-02 - 3.23E-01 | 7 / 28 | 3.20E-02 - 3.00E+00 | 2.88E-01 | 7.51E-01 |
| PCB 1260 | 8.44E-02 - 4.87E+00 | 6 / 35 | 4.79E-02 - 7.90E-01 | 3.15E-01 | 4.96E-01 |
| Phenanthrene | 1.64E-01 - 1.68E+01 | 18 / 28 | 3.20E-02 - 4.10E+00 | 2.64E+00 | 8.41E+00 |
| Pyrene | 1.48E-01 - 5.26E+01 | 24 / 28 | 4.20E-01 - 4.20E+00 | 4.17E+00 | 7.01E+00 |
| Tetrachloroethene | 2.00E-03 - 2.00E-03 | 1 / 23 | 2.00E-03 - 1.60E-01 | 4.57E-02 | 9.34E-01 |
| Toluene | 2.05E-01 - 2.05E-01 | 1 / 23 | 7.00E-03 - 1.00E-01 | 3.66E-02 | 1.23E-01 |
| **Inorganics** | | | | | |
| Aluminum | 6.68E+03 - 2.48E+04 | 35 / 35 | - | 1.42E+04 | 1.60E+04 |
| Arsenic | 3.20E+00 - 5.20E+01 | 35 / 35 | - | 1.39E+01 | 1.69E+01 |
| Barium | 2.40E+01 - 3.03E+02 | 35 / 35 | - | 6.58E+01 | 7.34E+01 |
| Beryllium | 1.92E-01 - 5.02E+00 | 23 / 35 | 4.27E-01 - 6.84E-01 | 6.45E-01 | 7.84E-01 |
| Boron | 1.06E+01 - 1.06E+01 | 1 / 3 | 7.37E+00 - 7.37E+00 | 5.99E+00 | 1.83E+02 |
| Cadmium | 7.71E-01 - 3.53E+00 | 4 / 35 | 4.47E-01 - 1.20E+00 | 6.92E-01 | 8.09E-01 |
| Calcium | 8.29E+02 - 9.82E+03 | 35 / 35 | - | 3.35E+03 | 4.00E+03 |
| Chromium | 1.29E+01 - 7.12E+01 | 35 / 35 | - | 2.40E+01 | 2.68E+01 |
| Cobalt | 5.09E+00 - 8.93E+01 | 35 / 35 | - | 1.55E+01 | 1.86E+01 |
| Copper | 2.26E+01 - 1.55E+03 | 35 / 35 | - | 1.00E+02 | 1.01E+02 |
| Iron | 1.73E+03 - 1.30E+05 | 35 / 35 | - | 2.86E+04 | 3.63E+04 |
| Lead | 3.78E+01 - 5.21E+02 | 33 / 34 | 5.47E+01 - 5.47E+01 | 2.13E+02 | 2.91E+02 |



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# Table 2-1 (cont'd.)

## Chemicals Identified in Soils (0-2 feet)

| Chemical | Range of Hits (mg/kg) | Frequency of Detection | Range of Quantitation Limits (mg/kg) | Arithmetic Mean (mg/kg) | Upper 95% Confidence Limit (mg/kg) |
|---|---|---|---|---|---|
| Magnesium | 1.73E+03 - 8.34E+03 | 35 / 35 | - | 4.07E+03 | 4.63E+03 |
| Manganese | 1.97E+02 - 1.29E+03 | 35 / 35 | - | 3.90E+02 | 4.41E+02 |
| Mercury | 6.50E-02 - 5.67E-01 | 28 / 35 | 2.80E-02 - 5.00E-02 | 1.96E-01 | 4.20E-01 |
| Nickel | 1.22E+01 - 9.92E+01 | 35 / 35 | - | 2.86E+01 | 3.38E+01 |
| Potassium | 4.86E+02 - 3.80E+03 | 35 / 35 | - | 1.16E+03 | 1.33E+03 |
| Silver | 5.50E-02 - 7.94E-01 | 3 / 35 | 3.40E-02 - 8.03E-01 | 3.18E-01 | 8.53E-01 |
| Sodium | 5.31E+01 - 6.93E+02 | 35 / 35 | - | 2.15E+02 | 2.64E+02 |
| Tin | 6.61E+00 - 6.61E+00 | 1 / 10 | 5.39E+00 - 5.81E+00 | 3.19E+00 | 3.79E+00 |
| Uranium | 1.51E-01 - 1.51E-01 | 1 / 10 | 1.08E-01 - 1.19E-01 | 6.68E-02 | 8.12E-02 |
| Vanadium | 2.37E+01 - 1.27E+02 | 35 / 35 | - | 5.15E+01 | 5.70E+01 |
| Zinc | 5.38E+01 - 8.49E+02 | 35 / 35 | - | 1.38E+02 | 1.57E+02 |
| Cyanide | 3.19E-01 - 4.29E-01 | 3 / 23 | 2.50E-01 - 5.00E+00 | 1.19E+00 | 4.10E+00 |

- The 95% upper confidence limit (UCL) of the mean concentration (based on log-normal distribution).

The distribution of the data was determined by plotting the data, which indicated that the majority of the chemicals did not display a normal distribution. As a result, the distribution of all chemicals was assumed to be lognormal. The following equation was used to calculate the upper 95% confidence limit of the mean for lognormally distributed data:

$$UCL = e^{(x + 0.5s^2 + sH/\sqrt{n-1})}$$

Where:

| | | |
|---|---|---|
| UCL | = | Upper 95% confidence limit. |
| e | = | Constant (base of the natural log, equal to 2.718). |
| x | = | Mean of the transformed data (log of the geometric mean). |
| s | = | Standard deviation of the transformed data. |
| H | = | H-statistic (Gilbert, 1987). |
| n | = | Number of samples. |

In calculating the arithmetic mean and 95% UCL of the mean, non-detects were incorporated as one-half the sample quantitation limit.

## 2.3 Selection of Chemicals of Potential Concern

Chemicals of potential concern were identified for the terrestrial ecological risk assessment based on a number of criteria including frequency of detection, screening values, and toxicity. In some instances, typical background values were also considered for certain inorganics. Table A-1 in Appendix A presents the rationale for excluding chemicals from the list of chemicals of potential concern. Thirty-one chemicals were screened out based on comparison with screening values. The screening values that were used are presented in Table A-2 (Appendix A), and were calculated based on a Northern short-tailed shrew ingesting soil, as well as earthworms that have accumulated contaminants from the soil. Ingestion rates and body weights for the shrew were obtained from the U.S. Environmental

Protection Agency's (EPA's) Wildlife Exposure Factors Handbook (EPA, 1993), and are discussed further in Subsection 3.4. The equations that were used to calculate the screening levels are presented in Tables A-3 and A-4. These screening values were compared to the maximum detected soil concentrations in the area of concern at the site. If the maximum detected concentrations fell below the screening values, then the chemical was screened out as a chemical of potential concern. There were a few instances where a chemical only slightly exceeded a screening value at a couple of locations (heptachlor epoxide, delta-hexachlorocyclohexane, methoxychlor, cobalt). These chemicals were also screened out.

Calcium, iron, and magnesium did not have screening levels, but were excluded as chemicals of potential concern based on low toxicity, and because the concentrations fell within typical background ranges as presented in Shacklette and Boerngen (1984), Kabata-Pendias and Pendias (1984), and NJDEPE (1992) (See Table A-8). Tin and uranium were excluded due to low frequency of detection and also because the detected concentrations fell within typical background ranges. In addition, uranium is shown to be naturally occurring and not from AMTL, since the ratio of the isotopes U-234/U-238 was approximately 1.0 for the samples taken during the Phase II remedial investigation. The ratio of these two isotopes for depleted uranium, the material used at AMTL, is typically 0.1, because the lighter isotope, U-234, is removed during the depletion process. Although aluminum exceeded screening values, it is a ubiquitous element, and the on-site concentrations fell within typical background levels. Thus, aluminum was also excluded as a chemical of potential concern.

Based on this screening, 17 organics and 8 inorganics were selected as chemicals of potential concern, and are presented in Table 2-2.

**Table 2-2**

**Chemicals of Potential Concern**

| Organics | Inorganics |
|---|---|
| Aroclor 1260 | Arsenic |
| Chlordane | Cadmium |
| DDD | Chromium |
| DDE | Copper |
| DDT | Lead |
| Dieldrin | Manganese |
| Endrin | Nickel |
| PAHs | Zinc |
| Benzo(a)anthracene | |
| Benzo(a)pyrene | |
| Benzo(b)fluoranthene | |
| Benzo(g,h,i)perylene | |
| Benzo(k)fluoranthene | |
| Chrysene | |
| Dibenz(a,h,)anthracene | |
| Fluoranthene | |
| Indeno(1,2,3-cd)pyrene | |
| Pyrene | |

## 3.0 EXPOSURE CHARACTERIZATION

The objectives of the exposure assessment are to:

- Identify habitats that have received or may receive chemicals from the site.
- Identify the plants and terrestrial wildlife that may be potentially exposed to the chemicals of potential concern.
- Select indicator or target species/communities.
- Identify significant pathways/routes by which target species are potentially exposed.
- Predict exposure doses for selected target species.

In characterizing ecological exposure, the potential magnitude and frequency by which ecological receptors are exposed to chemicals of potential concern are evaluated. In addition, the characterization evaluates all routes of exposure (*e.g.*, soil ingestion, plant ingestion) by which species inhabiting impacted areas may be exposed.

### 3.1 Habitat Evaluation

The initial step in characterizing exposure is to identify the on-site habitats that may be affected by the chemicals of potential concern, and subsequently, to determine appropriate receptor organisms for those habitats.

The location of the site and surrounding vicinity is shown in Figure 1-1. A more detailed map of the site is presented in Figure 2-1. The AMTL Site currently occupies 36.5 acres and is located in an urban area. The site, located on a former low bluff of the river, is generally flat, sloping slightly toward the river. As a result of more than a century of construction, most of the original topography has been covered by sand and gravel fill and construction debris. The majority of the AMTL site has limited potential as ecological habitat. Suitable habitat for terrestrial vegetation and wildlife is restricted to the southeast corner of the site, which is bordered by the Charles River to the south and west, by Talcott

Street to the east, and by a series of structures near the Commander's Quarters to the north (Figure 2-1). Because of the limited, lower quality habitat provided by the industrialized portion of the property, this ecological assessment focuses on the "southeast sector" of the site. This area encompasses approximately 11 acres, and includes a park, which is located between the Charles River and North Beacon Street, and consists of wooded areas as well as open grassy fields. The area to the north of North Beacon Street contains wooded sections along the roadways, as well as an open grassy area in the vicinity of the Commander's Quarters.

The open field and wooded areas identified on the site are locations where ecological receptors may be exposed to chemicals. The analytical results from the remedial investigation at the site show that chemicals of potential concern have been detected in soils in these areas. Appropriate ecological receptors are selected for evaluation, based on the potentially affected habitats at the site, chemical characterization of the site, and other site-specific considerations.

## 3.2 Selection of Indicator Species/Communities and Pathways of Exposure

This subsection presents the basis for the selection of indicator species and communities for evaluation in this assessment. In addition, exposure pathways are selected for each of the indicator species based on the assessment of the habitat types and the known chemical distributions at the site. All exposure pathways that are of little or no concern based on the analysis of site characteristics are eliminated. Emphasis is given to those pathways and species considered critical to the evaluation of ecological risk at the site.

The principal criteria used to select appropriate indicator species include:

- Species that occur on the site.
- Species that are threatened, endangered, or of special concern.
- Species that are critical to the structure and function of the particular ecosystem they inhabit.

- Species that serve as indicators of an important change in the ecosystem.
- Species that have a realistic and significant potential for exposure.
- Species for which sufficient exposure and/or toxicity data are available for evaluation.

Even though indicator species are selected for evaluation in the risk assessment, these species also represent the exposure that other similar species with comparable feeding habits may be receiving, and thus, serve as surrogate species.

Factors that have gone into the exposure pathway selection process include:

- Local topography.
- Local land use.
- Site-specific habitat conditions.
- Surrounding terrestrial habitat.
- Review of contaminant migration.
- Persistence and mobility of migrating pollutants.

The subsections that follow discuss the justification for the selection of indicator species and communities, as well as the selection of potential exposure routes.

### 3.2.1 Terrestrial Wildlife

In this assessment, it is assumed that exposure of terrestrial wildlife to the chemicals of potential concern occurs primarily when the animals feed in those areas affected by site contamination. Avian and mammalian species with the greatest potential for exposure were selected for evaluation. Species selected were representative of the principal habitat types present at the site. In addition, species were selected that represented a range of feeding relationships within these habitats. Although wildlife present at the AMTL Site may be exposed to the chemicals of potential concern through routes other than ingestion (*i.e.*, dermal absorption and inhalation), there is little scientific information available with which to assess these types of exposures. Therefore, these routes of exposure will not be evaluated in this assessment.

## Mammalian Species

The Northern short-tailed shrew (*Blarina brevicauda*) was selected as an indicator mammalian species for numerous reasons, including its almost exclusive insectivorous feeding habits, its limited home range (0.5 to 1.0 acre) (Burt and Grossenheider, 1980; Merritt, 1987), and its burrowing habits (makes tunnels into ground and snow). The short-tailed shrew is a commonly found species in New England (DeGraaf and Rudis, 1986), and is an inhabitant of forests, grasslands, marshes, and brushy areas (Merritt, 1987). Thus, the site is expected to provide adequate habitat for the shrew. In addition, the shrew is representative of the small mammal community that exists at the site. The shrew was evaluated for exposure to chemicals in soils through the ingestion of soil invertebrates (*i.e.*, earthworms) that may accumulate chemicals from their environment as well as through the incidental ingestion of soils while feeding, burrowing, and preening.

The white-footed mouse (*Peromyscus leucopus*) was also evaluated as an indicator species. The white-footed mouse was chosen due to its herbivorous diet, its limited home range (0.1 to 2.5 acres) (Burt and Grossenheider, 1980; Merritt, 1987), and because the site contains suitable habitat for this mouse. The white-footed mouse is most abundant in habitat that includes a canopy, such as brushy field and deciduous woodlots (EPA, 1993). The affected terrestrial habitats found on the AMTL property include both brushy and wooded areas. Both these areas on the site are expected to provide adequate habitat for the white-footed mouse. The white-footed mouse was evaluated for exposure to chemicals through the ingestion of vegetation that may accumulate chemicals from soil, as well as through the incidental ingestion of soils while feeding, burrowing, and preening.

## Avian Species

The American robin (*Turdus migratorius*) was chosen as an indicator species for passerine (*i.e.*, perching) birds in this assessment. The robin is expected to be one of the maximally exposed bird species at the site because of the potential for exposure to chemicals through the ingestion of invertebrates, particularly earthworms, which make up a large percentage

of its diet. In addition, the robin has a limited home range, from 0.11 to 0.75 acres (Young, 1951; Collins and Boyajian, 1965), and thus could be expected to obtain much of its dietary intake from the site. The robin is also a potential year-round resident at the site, and is representative of several predominantly ground-foraging omnivorous species potentially inhabiting the site. The robin was evaluated for exposure to chemicals in soils through the ingestion of soil invertebrates (*i.e.*, earthworms) that may accumulate chemicals from their environment, as well as through the incidental ingestion of soils while feeding.

The song sparrow (*Melospiza melodia*) was chosen for evaluation because it has been observed as a common breeder in the site vicinity (R. Stymeist, 1995; see Appendix D). In addition, the song sparrow has the potential for bioaccumulation of chemicals through the ingestion of plant material at the site, particularly seeds, which make up a large percentage of its diet. The song sparrow is also a potential year-round resident at the site, and is representative of several seed-eating bird species potentially inhabiting the site. The song sparrow was evaluated for exposure to chemicals in soils through the ingestion of seeds that may accumulate chemicals from their environment. In addition, the potential for exposure to chemicals through the incidental ingestion of soils while feeding was evaluated.

### 3.2.2 Terrestrial Vegetation

The terrestrial vegetation at the site consists primarily of grasses, shrubs, and deciduous trees. Chemicals in soil can enter a plant through four major pathways, including root uptake and translocation to aboveground plant parts; uptake from vapor; uptake from external contamination (dust and soil); and uptake and transport in oil cells (Bell, 1992). A direct comparison of soil concentrations with available phytotoxicity data was used to assess potential adverse effects on terrestrial vegetation.

### 3.2.3 Soil Invertebrates

Soil invertebrates, such as earthworms, are ecologically important because of their role in a number of processes including soil aeration, soil drainage, and soil fertility (EPA, 1992b).

Soil invertebrates can be exposed to contaminants in the soil through dermal absorption and soil ingestion. A direct comparison of soil concentrations with available soil invertebrate toxicity data was used to assess potential adverse effects on soil invertebrates.

#### 3.2.4 Endangered and Threatened Species

The Massachusetts Natural Heritage Society was contacted for information regarding potential endangered and threatened species in the vicinity of the site. The review found that there were no records of rare terrestrial or aquatic species or significant plant communities within the site area (Massachusetts Division of Fisheries and Wildlife, 1995).

#### 3.2.5 Summary

A summary of all exposure routes for each of the selected indicator species or communities is presented in Table 3-1.

### 3.3 Exposure Concentrations

Areas of exposure are selected for the indicator species/communities based on the assessment of habitats and the known distribution of the chemicals at the site. The concentrations at these areas of exposure are important in determining exposure doses and subsequent risk to receptors. Two exposure concentrations were used in assessing risk to birds and mammals - (1) the arithmetic mean, and (2) the 95% upper confidence limit (UCL) of the mean, or the maximum detected concentration, whichever value was lower. Both the arithmetic mean and 95% UCL were used to represent average exposure concentrations. The 95% UCL is presented in addition to the arithmetic mean because of the uncertainty associated with estimating the true average concentration at a site. Averages are used as the exposure concentrations since they are most representative of the concentration that would be contacted by mobile organisms at the site (EPA, 1992d). For

## Table 3-1

## Exposure Routes of Potential Concern to Ecological Receptors

---

**Indicator Species and Communities**

Northern short-tailed shrew (*Blarina brevicauda*)

- Ingestion of soil invertebrates (*i.e.*, earthworms)
- Incidental ingestion of soil

White-Footed Mouse (*Peromyscus leucopus*)

- Ingestion of vegetation (*i.e.*, seeds)
- Incidental ingestion of soil

American Robin (*Turdus migratorius*)

- Ingestion of soil invertebrates (*i.e.*, earthworms)
- Incidental ingestion of soil

Song Sparrow (*Melospiza melodia*)

- Ingestion of vegetation (*i.e.*, seeds)
- Incidental ingestion of soil

Terrestrial Plants

- Direct contact with soil
- Absorption/concentration from soil (seeds)

Soil Invertebrates

- Direct contact with soil
- Absorption/concentration from soil

---

stationary organisms (*e.g.*, plants), or organisms that would be expected to be found in a relatively small area (*i.e.*, soil invertebrates), each sample location was evaluated as a potential exposure concentration.

The exposure concentrations were based on soils data collected from 0-0.5 feet, 0.5-1.5 feet, and 0-2 feet. These soils were collected at the surface or near-surface, and represent the soil depths most likely to be contacted by ecological receptors. The exposure concentrations used in this assessment are presented in Table 3-2. As discussed in Subsection 2.2, the data were assumed to be lognormally distributed.

### 3.4 Estimation of Exposure Doses

This subsection discusses the methods by which chemical intakes are estimated for the selected indicator species. The models used to estimate exposure doses in milligrams of contaminant intake per kilogram of body weight per day (mg/kg-day) for the Northern short-tailed shrew, white-footed mouse, American robin, and song sparrow are presented here.

#### 3.4.1 Northern Short-Tailed Shrew

Primary routes of potential exposure to the short-tailed shrew include the ingestion of soil invertebrates and the incidental ingestion of surface soil. The methodology used to calculate the exposure for the shrew and the associated assumptions are presented in the following paragraphs.

**Ingestion of Soil Invertebrates**

Diets are variable among species of shrew, but in general, they are composed of earthworms, insects, and other invertebrates (DeGraaf and Rudis, 1986). The composition and quantity of the diet of the shrew can also vary with season and availability of resources as well as health, age, and sex of the species. For this assessment potential exposure to the

## Table 3-2
## Exposure Concentrations (mg/kg)

| Chemical | Soil Concentration (mg/kg) | |
|---|---|---|
| | Mean | Upper 95% Confidence Limit |
| **Organics** | | |
| Chlordane | 1.67E+00 | 5.64E+00 |
| DDD | 2.41E-01 | 8.19E-01 |
| DDE | 5.61E-01 | 2.57E+00 |
| DDT | 8.01E-01 | 4.61E+00 |
| Dieldrin | 3.43E-02 | 9.67E-02 |
| Endrin | 2.70E-01 | 5.00E-01[a] |
| PAHs | | |
| Benzo(a)anthracene | 2.33E+00 | 7.83E+00 |
| Benzo(a)pyrene | 2.62E+00 | 3.63E+00 |
| Benzo(b)fluoranthene | 1.72E+00 | 3.94E+00 |
| Benzo(g,h,i)perylene | 1.53E+00 | 4.44E+00 |
| Benzo(k)fluoranthene | 2.30E+00 | 6.06E+00 |
| Chrysene | 2.36E+00 | 1.31E+01 |
| Dibenz(a,h,)anthracene | 3.75E-01 | 4.65E-01 |
| Fluoranthene | 3.57E+00 | 5.55E+00 |
| Indeno(1,2,3-cd)pyrene | 1.87E+00 | 4.09E+00 |
| Pyrene | 4.17E+00 | 7.01E+00 |
| PCB (Aroclor 1260) | 3.15E-01 | 4.96E-01 |
| **Inorganics** | | |
| Arsenic | 1.39E+01 | 1.69E+01 |
| Cadmium | 6.92E-01 | 8.09E-01 |
| Chromium | 2.41E+01 | 2.68E+01 |
| Copper | 1.00E+02 | 1.01E+02 |
| Lead | 2.13E+02 | 2.91E+02 |
| Manganese | 3.90E+02 | 4.41E+02 |
| Nickel | 2.86E+01 | 3.38E+01 |
| Zinc | 1.38E+02 | 1.57E+02 |

[a] This value represents the maximum detected concentration.

short-tailed shrew from chemicals of concern in its daily diet was evaluated for the consumption of earthworms. Although the diet of the shrew does not consist entirely of earthworms, the earthworm was used to represent a typical soil invertebrate potentially ingested by the shrew since, (1) the earthworm is one of the few invertebrates for which chemical uptake can be estimated, and (2) earthworms would be expected to significantly bioaccumulate chemicals found in the soil as a result of both dermal absorption and soil ingestion. Because earthworms demonstrate a higher potential for bioaccumulation than other soil invertebrates, it is likely that the use of earthworms represents a conservative estimate of the potential exposure to the shrew.

The exposure doses to the short-tailed shrew through ingestion of earthworms were determined using the approach and assumptions as presented in Table 3-3. The estimation of chemical concentrations in earthworms is discussed in Appendix B. The daily earthworm ingestion rate for the short-tailed shrew was assumed to be 0.62 g wet weight/g body weight per day based on information for male and female adult short-tailed shrews which were fed a diet of beef liver (EPA, 1993). Assuming a mean body weight of 15 grams for an adult short-tailed shrew (EPA, 1993), a wet weight ingestion rate of 9.3 grams was estimated. A dry weight dietary intake of 2.8 g/day was estimated from the wet weight ingestion rate of 9.3 g/day, based on a water content of 69.7% in the study diet (*i.e.*, beef liver) (Baes et al., 1984). The wet weight ingestion rate of 9.3 g/day or 0.62 g/g/day is similar to ingestion rates reported for the short-tailed shrew in other sources (Opresko et al., 1994; Churchill, 1990). Baker (1983), however, reported that short-tailed shrews consume 50 -300% of their body weight per day in food. This is a higher ingestion rate than was reported in other references, and is assessed in the Uncertainty Analysis (Section 6).

The home range of the short-tailed shrew ranges from 0.5 to 1 acre (Burt and Grossenheider, 1980; Merritt, 1987). Since this falls within the area of the site, it was assumed that 100% of the shrew's forage would be obtained from within the boundaries of the site.

## Table 3-3

## Model for Calculating Doses to the Northern Short-Tailed Shrew Through the Ingestion of Earthworms

$$\text{Earthworm Ingestion Dose (mg/kg-day)} = \frac{CE \times IR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CE | = | Chemical concentration in earthworms (mg/kg) |
| IR | = | Earthworm ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| CE | = | Earthworm concentrations (mg/kg) are presented in Table B-2 (Appendix B). |
| IR | = | 2.8 g dry weight/day (EPA, 1993) |
| FI | = | 1[a] |
| BW | = | 0.015 kg (EPA, 1993) |
| CF | = | 1000 g/kg |

[a]Assumes home range of the shrew falls within the site area.

## Incidental Ingestion of Soil

The short-tailed shrew may also be exposed to chemicals through the incidental ingestion of surface soil. Mammals with feeding and burrowing habits, such as the shrew can inadvertently ingest surface soil while consuming soil invertebrates or while preening or burrowing. The model and assumptions used to estimate exposure doses to the short-tailed shrew through soil ingestion is presented in Table 3-4.

Data regarding the incidental soil ingestion rate of the short-tailed shrew were not available. EPA (1993) reports that the percent soil in the diet of a woodcock, which feeds extensively on earthworms, is approximately 10.4%. EPA (1993) further suggests that other species that ingest earthworms might be expected to have similar soil intakes. A best estimate of 10.4% of the dry weight dietary ingestion rate was used for the short-tailed shrew's incidental soil ingestion rate. A dry weight soil ingestion rate of 0.29 g/day was calculated for the shrew based on 10.4% of its dry weight dietary intake of 2.8 g/day.

## Total Exposure to the Northern Short-tailed Shrew

Based on the previous discussion, the total exposure of the shrew to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{worm} + Dose_{soil}$$

Where:

| | | |
|---|---|---|
| $Dose_{Total}$ | = | Total dose (mg/kg-day). |
| $Dose_{worm}$ | = | Dose from ingestion of earthworms (mg/kg-day). |
| $Dose_{soil}$ | = | Dose from soil ingestion (mg/kg-day). |

The total and route-specific exposure doses estimated for the shrew are presented in Table 3-5.

## Table 3-4

## Model for Calculating Doses to the Northern Short-Tailed Shrew Through the Incidental Ingestion of Soil

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CS | = | Chemical concentration in surface soil (mg/kg) |
| SIR | = | Soil ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |
| **Exposure Assumptions** | | |
| CS | = | Surface soil concentrations (mg/kg) are presented in Table 2-1. |
| SIR | = | 0.29 g dry weight/day[a] |
| FI | = | 1[b] |
| BW | = | 0.015 kg (EPA, 1993) |
| CF | = | 1000 g/kg |

[a]Assumed to be 10.4% of food intake (EPA, 1993).
[b]Assumes home range of the shrew falls within the site area.

## Table 3-5

## Exposure Doses Estimated for the Northern Short-Tailed Shrew (mg/kg-day)

| Chemical | Soil Ingestion Dose | | Earthworm Ingestion Dose | | Total Dose | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 3.23E-02 | 1.09E-01 | 1.56E+00 | 5.26E+00 | 1.59E+00 | 5.37E+00 |
| DDD | 4.66E-03 | 1.58E-02 | 3.73E-01 | 1.27E+00 | 3.78E-01 | 1.28E+00 |
| DDE | 1.08E-02 | 4.97E-02 | 7.75E-01 | 3.55E+00 | 7.86E-01 | 3.60E+00 |
| DDT | 1.55E-02 | 8.91E-02 | 1.58E+00 | 9.12E+00 | 1.60E+00 | 9.21E+00 |
| Dieldrin | 6.63E-04 | 1.87E-03 | 6.34E-02 | 1.79E-01 | 6.40E-02 | 1.81E-01 |
| Endrin | 5.22E-03 | 9.67E-03 | 1.81E-01 | 3.36E-01 | 1.87E-01 | 3.46E-01 |
| PAHs (total) | 4.42E-01 | 1.08E+00 | 1.41E+00 | 3.47E+00 | 1.85E+00 | 4.55E+00 |
| Benzo(a)anthracene | 4.50E-02 | 1.51E-01 | 1.17E-01 | 3.95E-01 | 1.62E-01 | 5.46E-01 |
| Benzo(a)pyrene | 5.07E-02 | 7.02E-02 | 1.66E-01 | 2.30E-01 | 2.17E-01 | 3.01E-01 |
| Benzo(b)fluoranthene | 3.33E-02 | 7.62E-02 | 6.74E-02 | 1.54E-01 | 1.01E-01 | 2.31E-01 |
| Benzo(g,h,i)perylene | 2.96E-02 | 8.58E-02 | 4.28E-02 | 1.24E-01 | 7.24E-02 | 2.10E-01 |
| Benzo(k)fluoranthene | 4.45E-02 | 1.17E-01 | 9.02E-02 | 2.38E-01 | 1.35E-01 | 3.55E-01 |
| Chrysene | 4.56E-02 | 2.53E-01 | 1.94E-01 | 1.08E+00 | 2.39E-01 | 1.33E+00 |
| Dibenz(a,h)anthracene | 7.25E-03 | 8.99E-03 | 3.43E-02 | 4.25E-02 | 4.16E-02 | 5.15E-02 |
| Fluoranthene | 6.90E-02 | 1.07E-01 | 2.47E-01 | 3.83E-01 | 3.16E-01 | 4.91E-01 |
| Indeno(1,2,3-cd)pyrene | 3.62E-02 | 7.91E-02 | 1.43E-01 | 3.13E-01 | 1.79E-01 | 3.92E-01 |
| Pyrene | 8.06E-02 | 1.36E-01 | 3.04E-01 | 5.10E-01 | 3.84E-01 | 6.46E-01 |
| PCB (Aroclor 1260) | 6.09E-03 | 9.59E-03 | 1.29E+00 | 2.04E+00 | 1.30E+00 | 2.05E+00 |
| **Inorganics** | | | | | | |
| Arsenic | 2.69E-01 | 3.27E-01 | 1.25E-01 | 1.51E-01 | 3.93E-01 | 4.78E-01 |
| Cadmium | 1.34E-02 | 1.56E-02 | 5.94E-01 | 6.95E-01 | 6.08E-01 | 7.10E-01 |
| Chromium | 4.64E-01 | 5.18E-01 | 3.45E+00 | 3.85E+00 | 3.91E+00 | 4.37E+00 |
| Copper | 1.93E+00 | 1.95E+00 | 8.21E+00 | 8.30E+00 | 1.01E+01 | 1.02E+01 |
| Lead | 4.12E+00 | 5.63E+00 | 2.11E+01 | 2.88E+01 | 2.52E+01 | 3.44E+01 |
| Manganese | 7.54E+00 | 8.53E+00 | 8.01E+00 | 9.06E+00 | 1.55E+01 | 1.76E+01 |
| Nickel | 5.53E-01 | 6.53E-01 | 9.61E+00 | 1.14E+01 | 1.02E+01 | 1.20E+01 |
| Zinc | 2.67E+00 | 3.04E+00 | 2.55E+02 | 2.90E+02 | 2.58E+02 | 2.93E+02 |

### 3.4.2 White-Footed Mouse

Primary routes of potential on-site exposure for the white-footed mouse include the ingestion of plant material (*i.e.*, seeds) and incidental ingestion of soil. The methodology used to calculate the various exposures to the mouse and the associated assumptions are presented in the following paragraphs.

<u>**Ingestion of Plant Seeds**</u>

The diet of the white-footed mouse consists mainly of seeds, nuts, and insects (Burt and Grossenheider, 1976). The composition and quantity of a white-footed mouse's diet can vary with season and availability of resources as well as health, age, and sex of the species (Chapman and Feldhamer, 1982). However, for this assessment, potential exposure to the white-footed mouse from chemicals of potential concern in its daily diet was only evaluated for the consumption of plant seeds. Sufficient information does not exist with which to estimate chemical uptake in other dietary items. Because the mouse's reported home range of 0.1 to 2.5 acres (Burt and Grossenheider, 1980; Merritt, 1987) is less than the total area of the site, 100% of the mouse's foraging time is assumed to occur in contaminated areas. The exposure doses to the white-footed mouse through ingestion of seeds were determined using the approach and assumptions as presented in Table 3-6. The ingestion rate for white-footed mice was assumed to be 0.2 g wet weight/g body weight per day, which is the midpoint of the reported range (0.18 - 0.22 g/g-day) for nonbreeding adult deer mice (*Peromyscus maniculatus*) (EPA, 1993). The white-footed mouse and deer mouse are morphologically, behaviorally, and ecologically similar (Wolff, 1985), and thus it was assumed that their ingestion rates would also be similar. The midpoint of the body weights reported for adult white-footed mice was 20 g (based on a range of 13 to 27 g) (Merritt, 1987). Thus, a daily wet weight ingestion rate of 4 g/day was estimated. A dry weight dietary intake of 3.9 g/day was estimated from the wet weight ingestion rate, based on a water content of 3% in the laboratory rat chow diet (EPA, 1993). The estimation of chemical concentrations in plant seeds is discussed further in Appendix C.

## Table 3-6

## Model for Calculating Doses to the White-Footed Mouse Through the Ingestion of Plant Seeds

$$\text{Seed Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CS | = | Chemical concentration in seeds (mg/kg dry weight) |
| SIR | = | Seed ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |
| **Exposure Assumptions** | | |
| CS | = | Seed concentrations (mg/kg) are presented in Table C-2 (Appendix C). |
| SIR | = | 3.9 g dry weight/day (EPA, 1993) |
| FI | = | 1[a] |
| BW | = | 0.020 kg (Merritt, 1987) |
| CF | = | 1000 g/kg |

[a]Assumes home range of the mouse falls within the site area.

### Incidental Ingestion of Soil

The white-footed mouse may also be exposed to chemicals through the incidental ingestion of surface soil. Mammals with ground foraging and nesting habits such as the white-footed mouse tend to have increased exposure to surface soils. Therefore, it was assumed that the mouse may inadvertently ingest surface soil while consuming plant seeds or while preening, nesting, or foraging. The exposure doses to the white-footed mouse through incidental ingestion of soil were determined using the approach and assumptions as presented in Table 3-7.

It has been estimated that less than 2% of the dry weight dietary intake of the white-footed mouse consists of soil (EPA, 1993). For this assessment it was assumed that soil intake is 2% of the dietary intake. A dry weight soil ingestion rate of 0.078 g/day was calculated for the deer mouse based on 2% of its dry weight dietary intake of 3.9 g/day.

### Total Exposure to the White-Footed Mouse

Based on the previous discussion, the total exposure of the white-footed mouse to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{plant} + Dose_{soil}$$

Where:

| | | |
|---|---|---|
| $Dose_{Total}$ | = | Total dose (mg/kg-day). |
| $Dose_{plant}$ | = | Dose from ingestion of plant seeds (mg/kg-day). |
| $Dose_{soil}$ | = | Dose from soil ingestion (mg/kg-day). |

The total and route-specific exposure doses estimated for the white-footed mouse are presented in Table 3-8.

## Table 3-7

## Model for Calculating Doses to the White-Footed Mouse Through the Incidental Ingestion of Soil

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CS | = | Chemical concentration in surface soil (mg/kg) |
| SIR | = | Soil ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| CS | = | Surface soil concentrations (mg/kg) are presented in Table 2-1. |
| SIR | = | 0.078 g dry weight/day[a] |
| FI | = | 1[b] |
| BW | = | 0.020 kg (Merritt, 1987) |
| CF | = | 1000 g/kg |

[a]Assumed to be 2% of food intake (EPA, 1993).
[b]Assumes home range of the white-footed mouse falls within the site area.

## Table 3-8

## Exposure Doses Estimated for the White-footed Mouse (mg/kg-day)

| Chemical | Soil Ingestion Dose | | Seed Ingestion Dose | | Total Dose | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 6.51E-03 | 2.20E-02 | 3.12E-01 | 1.05E+00 | 3.18E-01 | 1.07E+00 |
| DDD | 9.40E-04 | 3.19E-03 | 6.30E-04 | 2.14E-03 | 1.57E-03 | 5.33E-03 |
| DDE | 2.19E-03 | 1.00E-02 | 2.36E-03 | 1.08E-02 | 4.55E-03 | 2.08E-02 |
| DDT | 3.12E-03 | 1.80E-02 | 9.01E-03 | 5.19E-02 | 1.21E-02 | 6.98E-02 |
| Dieldrin | 1.34E-04 | 3.77E-04 | 2.33E-03 | 6.56E-03 | 2.46E-03 | 6.94E-03 |
| Endrin | 1.05E-03 | 1.95E-03 | 1.83E-02 | 3.39E-02 | 1.94E-02 | 3.59E-02 |
| PAHs (total) | 8.91E-02 | 2.19E-01 | 2.13E-01 | 3.93E-01 | 3.02E-01 | 6.12E-01 |
| Benzo(a)anthracene | 9.09E-03 | 3.05E-02 | 1.00E-02 | 3.37E-02 | 1.91E-02 | 6.43E-02 |
| Benzo(a)pyrene | 1.02E-02 | 1.42E-02 | 9.04E-02 | 1.25E-01 | 1.01E-01 | 1.39E-01 |
| Benzo(b)fluoranthene | 6.71E-03 | 1.54E-02 | 4.09E-03 | 9.37E-03 | 1.08E-02 | 2.47E-02 |
| Benzo(g,h,i)perylene | 5.97E-03 | 1.73E-02 | 1.99E-03 | 5.78E-03 | 7.96E-03 | 2.31E-02 |
| Benzo(k)fluoranthene | 8.97E-03 | 2.36E-02 | 5.47E-03 | 1.44E-02 | 1.44E-02 | 3.81E-02 |
| Chrysene | 9.20E-03 | 5.11E-02 | 1.02E-02 | 5.65E-02 | 1.94E-02 | 1.08E-01 |
| Dibenz(a,h)anthracene | 1.46E-03 | 1.81E-03 | 1.00E-03 | 1.24E-03 | 2.46E-03 | 3.06E-03 |
| Fluoranthene | 1.39E-02 | 2.16E-02 | 3.97E-02 | 6.17E-02 | 5.36E-02 | 8.33E-02 |
| Indeno(1,2,3-cd)pyrene | 7.29E-03 | 1.60E-02 | 2.44E-03 | 5.33E-03 | 9.73E-03 | 2.13E-02 |
| Pyrene | 1.63E-02 | 2.73E-02 | 4.76E-02 | 8.00E-02 | 6.38E-02 | 1.07E-01 |
| PCB (Aroclor 1260) | 1.23E-03 | 1.93E-03 | 7.00E-04 | 1.10E-03 | 1.93E-03 | 3.04E-03 |
| **Inorganics** | | | | | | |
| Arsenic | 5.42E-02 | 6.59E-02 | 1.63E-02 | 1.98E-02 | 7.05E-02 | 8.57E-02 |
| Cadmium | 2.70E-03 | 3.16E-03 | 2.02E-02 | 2.37E-02 | 2.29E-02 | 2.68E-02 |
| Chromium | 9.36E-02 | 1.05E-01 | 2.11E-02 | 2.35E-02 | 1.15E-01 | 1.28E-01 |
| Copper | 3.90E-01 | 3.94E-01 | 4.88E+00 | 4.92E+00 | 5.27E+00 | 5.32E+00 |
| Lead | 8.31E-01 | 1.13E+00 | 3.74E-01 | 5.11E-01 | 1.20E+00 | 1.65E+00 |
| Manganese | 1.52E+00 | 1.72E+00 | 3.80E+00 | 4.30E+00 | 5.32E+00 | 6.02E+00 |
| Nickel | 1.12E-01 | 1.32E-01 | 3.35E-01 | 3.95E-01 | 4.46E-01 | 5.27E-01 |
| Zinc | 5.38E-01 | 6.12E-01 | 2.42E+01 | 2.76E+01 | 2.48E+01 | 2.82E+01 |



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### 3.4.3 American Robin

The primary routes of potential on-site exposure that were evaluated for the American robin include the ingestion of soil invertebrates and the incidental ingestion of soil. The methodology used to calculate the exposure doses for the robin and the associated assumptions are presented in the following paragraphs.

**Ingestion of Soil Invertebrates**

The American robin, like most members of the thrush family (Turdinae), is primarily a ground forager and feeds on fruits, insects and earthworms (Graber et al., 1971). For this assessment potential exposure to the robin from chemicals of concern in its diet was evaluated based on the consumption of earthworms. Although the diet of the robin does not consist entirely of earthworms, for this assessment it is assumed that earthworms are the primary source of all dietary exposure. The primary reasons for making this assumption are: (1) the earthworm is one of the few invertebrates for which chemical uptake can be estimated, and (2) earthworms would be expected to significantly bioaccumulate chemicals found in the soil as a result of both dermal absorption and soil ingestion. Because earthworms demonstrate a higher potential for bioaccumulation than other soil invertebrates, it is likely that the use of earthworms represents a conservative estimate of the potential exposure to the American robin.

The model and assumptions used to estimate daily doses for the robin based on ingestion of chemicals of concern in invertebrates (*i.e.*, earthworms) are shown in Table 3-9. In a study by Nagy (1987), field metabolic rates for approximately 10 species of passerine birds were analyzed. Body weights were strongly correlated to bird metabolic rates. In determining an appropriate ingestion rate for the robin, the following model from Nagy (1987) was used to represent the relationship between field metabolic rate and body weight:

## Table 3-9

## Model for Calculating Doses to the American Robin Through the Ingestion of Earthworms

$$\text{Earthworm Ingestion Dose (mg/kg-day)} = \frac{CE \times IR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CE | = | Chemical concentration in earthworms (mg/kg) |
| IR | = | Earthworm ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| CE | = | Earthworm concentrations (mg/kg) are presented in Table B-2 (Appendix B). |
| IR | = | 16 g dry weight/day (Nagy, 1987; EPA, 1993) |
| FI | = | 1[a] |
| BW | = | 0.077 kg (Dunning, 1984) |
| CF | = | 1000 g/kg |

[a]Assumes home range of the robin falls within the site area.

$$FMR = 2.123 \times BW^{0.749}$$

Where,

FMR = Field metabolic rate (kcal/day)

BW = Body weight (g)

Assuming an average robin body weight of 77 grams (Dunning, 1984), a field metabolic rate of approximately 55 kcal/day was calculated. In order to convert this field metabolic rate to an ingestion rate, information on the energy content in earthworms was used. The gross energy content of earthworms is approximately 4.6 kcal/g dry weight (EPA, 1993). The amount of metabolizable energy in an earthworm is equal to the gross energy multiplied by an assimilation efficiency factor. Although an assimilation efficiency factor was not available for earthworms, assimilation efficiency values of 72-79% have been reported for animal matter in the diet of birds (EPA, 1993). The midpoint of these range of values (76%) was assumed for earthworms. Thus, the amount of metabolizable energy in an earthworm was estimated to be 3.5 kcal/g dry weight. Based on this information, a dry weight ingestion rate of 16 g/day was estimated for the robin (*i.e.*, 55 kcal/day ÷ 3.5 kcal/g). The calculation of chemical concentrations in earthworms is presented in Appendix B.

The dietary intake of the robin is assumed to occur solely in contaminated areas for each of the sites, because the robin's home range of 0.11 to 0.75 acres is less than the total area of the site (Collins and Boyajan, 1965; Young, 1951).

**Incidental Ingestion of Soil**

The robin may ingest soil inadvertently while consuming earthworms and other ground-dwelling prey, and while preening. The model and assumptions used to calculate a soil ingestion dose for the robin are presented in Table 3-10.

Data regarding the incidental soil ingestion rate of the American robin were not available. EPA (1993) reports that the percent soil in the diet of a woodcock, which feeds extensively

**Table 3-10**

**Model for Calculating Doses to the American Robin Through the Incidental Ingestion of Soil**

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CS | = | Chemical concentration in surface soil (mg/kg) |
| SIR | = | Soil ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |
| **Exposure Assumptions** | | |
| CS | = | Surface soil concentrations (mg/kg) are presented in Table 2-1. |
| SIR | = | 1.7 g dry weight/day[a] |
| FI | = | 1[b] |
| BW | = | 0.077 kg (Dunning, 1984) |
| CF | = | 1000 g/kg |

[a]Assumed to be 10.4% of food intake (EPA, 1993).
[b]Assumes home range of the robin falls within the site area.

on earthworms, is approximately 10.4%. EPA (1993) further suggests that other species that ingest earthworms might be expected to have similar soil intakes. A best estimate of 10.4% of the dry weight dietary ingestion rate was used for the robin's incidental soil ingestion rate. A soil ingestion rate of 1.7 g dry weight/day was assumed for the robin based on a dietary intake of 16 g dry weight/day.

**Total Exposure to the American Robin**

Based on the previous discussion, the total exposure of the robin to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{worm} + Dose_{soil}$$

Where:

| | | |
|---|---|---|
| $Dose_{Total}$ | = | Total dose (mg/kg-day). |
| $Dose_{worm}$ | = | Dose from ingestion of earthworms (mg/kg-day). |
| $Dose_{soil}$ | = | Dose from soil ingestion (mg/kg-day). |

The total and route-specific exposure doses estimated for the robin are presented in Table 3-11.

### 3.4.4 Song Sparrow

The primary routes of potential on-site exposure that were evaluated for the song sparrow include the ingestion of plant material and the incidental ingestion of soil. The methodology used to calculate the exposure doses for the sparrow and the associated assumptions are presented in the following paragraphs.

## Table 3-11

## Exposure Doses Estimated for the American Robin (mg/kg-day)

| Chemical | Soil Ingestion Dose | | Earthworm Ingestion Dose | | Total Dose | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 3.69E-02 | 1.25E-01 | 1.74E+00 | 5.86E+00 | 1.77E+00 | 5.98E+00 |
| DDD | 5.32E-03 | 1.81E-02 | 4.16E-01 | 1.41E+00 | 4.21E-01 | 1.43E+00 |
| DDE | 1.24E-02 | 5.67E-02 | 8.63E-01 | 3.95E+00 | 8.75E-01 | 4.01E+00 |
| DDT | 1.77E-02 | 1.02E-01 | 1.76E+00 | 1.02E+01 | 1.78E+00 | 1.03E+01 |
| Dieldrin | 7.57E-04 | 2.13E-03 | 7.06E-02 | 1.99E-01 | 7.13E-02 | 2.01E-01 |
| Endrin | 5.96E-03 | 1.10E-02 | 2.02E-01 | 3.74E-01 | 2.08E-01 | 3.85E-01 |
| PAHs (total) | 5.04E-01 | 1.24E+00 | 1.56E+00 | 3.86E+00 | 2.07E+00 | 5.10E+00 |
| Benzo(a)anthracene | 5.14E-02 | 1.73E-01 | 1.31E-01 | 4.39E-01 | 1.82E-01 | 6.12E-01 |
| Benzo(a)pyrene | 5.78E-02 | 8.01E-02 | 1.85E-01 | 2.56E-01 | 2.43E-01 | 3.37E-01 |
| Benzo(b)fluoranthene | 3.80E-02 | 8.70E-02 | 7.51E-02 | 1.72E-01 | 1.13E-01 | 2.59E-01 |
| Benzo(g,h,i)perylene | 3.38E-02 | 9.80E-02 | 4.77E-02 | 1.38E-01 | 8.15E-02 | 2.36E-01 |
| Benzo(k)fluoranthene | 5.08E-02 | 1.34E-01 | 1.00E-01 | 2.64E-01 | 1.51E-01 | 3.98E-01 |
| Chrysene | 5.21E-02 | 2.89E-01 | 2.16E-01 | 1.20E+00 | 2.68E-01 | 1.49E+00 |
| Dibenz(a,h)anthracene | 8.28E-03 | 1.03E-02 | 3.82E-02 | 4.73E-02 | 4.65E-02 | 5.76E-02 |
| Fluoranthene | 7.88E-02 | 1.23E-01 | 2.74E-01 | 4.27E-01 | 3.53E-01 | 5.49E-01 |
| Indeno(1,2,3-cd)pyrene | 4.13E-02 | 9.03E-02 | 1.59E-01 | 3.48E-01 | 2.01E-01 | 4.39E-01 |
| Pyrene | 9.21E-02 | 1.55E-01 | 3.38E-01 | 5.68E-01 | 4.30E-01 | 7.23E-01 |
| PCB (Aroclor 1260) | 6.95E-03 | 1.10E-02 | 1.44E+00 | 2.27E+00 | 1.45E+00 | 2.28E+00 |
| **Inorganics** | | | | | | |
| Arsenic | 3.07E-01 | 3.73E-01 | 1.39E-01 | 1.69E-01 | 4.46E-01 | 5.42E-01 |
| Cadmium | 1.53E-02 | 1.79E-02 | 6.61E-01 | 7.73E-01 | 6.77E-01 | 7.91E-01 |
| Chromium | 5.30E-01 | 5.92E-01 | 3.84E+00 | 4.29E+00 | 4.37E+00 | 4.88E+00 |
| Copper | 2.21E+00 | 2.23E+00 | 9.14E+00 | 9.23E+00 | 1.14E+01 | 1.15E+01 |
| Lead | 4.70E+00 | 6.42E+00 | 2.35E+01 | 3.20E+01 | 2.82E+01 | 3.85E+01 |
| Manganese | 8.61E+00 | 9.74E+00 | 8.91E+00 | 1.01E+01 | 1.75E+01 | 1.98E+01 |
| Nickel | 6.31E-01 | 7.46E-01 | 1.07E+01 | 1.26E+01 | 1.13E+01 | 1.34E+01 |
| Zinc | 3.05E+00 | 3.47E+00 | 2.84E+02 | 3.23E+02 | 2.87E+02 | 3.26E+02 |

## Ingestion of Plant Seeds

Seeds of grasses and weeds consist of approximately 75% of the song sparrow's yearly diet; and up to 92% of the sparrow's fall diet. Insects and other invertebrates comprise the remainder of the sparrow's diet (Martin et al., 1961). Although a bird's diet can vary with season and availability of resources, for this assessment it was assumed that the sparrow's diet consists entirely of plant seeds.

The exposure doses to the sparrow through the ingestion of plant seeds were determined using the approach and assumptions presented in Table 3-12. In a study by Nagy (1987), approximately 10 species of passerine birds were studied for correlation between individual metabolic rates and body weights. Some of the species of passerines studied by Nagy had body weights and foraging habits similar to the song sparrow's. To determine an appropriate ingestion rate for the sparrow, the following model from Nagy (1987) was used to represent the relationship between field metabolic rate and body weight:

$$FMR = 2.123 * BW^{0.749}$$

Where:

FMR = Field metabolic rate (kcal/day)

BW = Body weight (g)

Placing the average male and female song sparrow body weight of 20.8 grams (Dunning, 1984) in this model results in a field metabolic rate of approximately 20.6 kcal/day. This is very similar to an 85 kjoules/day (*i.e.*, 20.3 kcal/day) energy requirement, as reported in the literature for the chipping sparrow (Pulliam, 1985). Assuming that the usable energy in seeds is 16 joules/mg (3.8 kcal/g) (Pulliam, 1985), a dry weight ingestion rate of 5.4 g/day was estimated for the song sparrow (*i.e.*, 20.6 kcal/day ÷ 3.8 kcal/g). The methods for calculating the chemical concentrations in seeds is presented in Appendix C.

The fraction of the sparrow's dietary intake that it ingests from a particular site is dependent on the size of its home range in relation to the size of the site. Because the sparrow's home

## Table 3-12

### Model for Calculating Doses to the Song Sparrow Through the Ingestion of Plant Seeds

$$\text{Seed Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CS | = | Chemical concentration in seeds (mg/kg dry weight) |
| SIR | = | Seed ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| CS | = | Seed concentrations (mg/kg) are presented in Table C-2 (Appendix C). |
| SIR | = | 5.4 g dry weight/day (Nagy, 1987; Pulliam, 1985) |
| FI | = | 1[a] |
| BW | = | 0.0208 kg (Dunning, 1984) |
| CF | = | 1000 g/kg |

[a]Assumes home range of the sparrow falls within the site area.

range of 0.5 to 1.5 acres (DeGraaf and Rudis, 1986) is less than the total area of the site, 100% of the sparrow's foraging is assumed to occur at the site.

**Incidental Ingestion of Soil**

The song sparrow may also be exposed to chemicals through incidental soil ingestion. Birds inadvertently ingest soil while ground foraging, preening, and nesting. The exposure doses to the song sparrow through the incidental ingestion of soil were determined using the approach and assumptions presented in Table 3-13.

Young and Cockerham (1985) reported relatively higher liver concentrations of TCDD for Southern meadowlarks residing around a TCDD-contaminated site at Eglin Air Force Base, Florida. They hypothesized that the Southern meadowlark ingested soil while preening and foraging for soil-borne insects. Based on this report, it was assumed that the song sparrow's soil intake is between 0.1 and 10% of its dietary intake. A best estimate of 1% of the dry weight dietary ingestion rate was used for the sparrow's incidental soil ingestion rate, based on a similar assumption made by EPA for the Eastern meadowlark (EPA, 1990a). A dry weight soil ingestion rate of 0.054 g/day was calculated for the song sparrow based on 1% of the sparrow's dietary intake of 5.4 g/day.

**Total Exposure to the Song Sparrow**

Based on the previous discussion, the total exposure of the song sparrow to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{plant} + Dose_{soil}$$

Where:

| | | |
|---|---|---|
| $Dose_{Total}$ | = | Total dose (mg/kg-day). |
| $Dose_{plant}$ | = | Dose from ingestion of plant seeds (mg/kg-day). |
| $Dose_{soil}$ | = | Dose from soil ingestion (mg/kg-day). |

## Table 3-13

### Model for Calculating Doses to the Song Sparrow Through the Incidental Ingestion of Soil

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

**Where:**

| | | |
|---|---|---|
| CS | = | Chemical concentration in surface soil (mg/kg) |
| SIR | = | Soil ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| CS | = | Surface soil concentrations are presented in Table 2-1. |
| SIR | = | 0.054 g dry weight/day[a] |
| FI | = | 1[b] |
| BW | = | 0.0208 kg (Dunning, 1984) |
| CF | = | 1000 g/kg |

[a]Assumed to be 1% of food intake (EPA, 1990).
[b]Assumes home range of the sparrow falls within the site area.

The total and route-specific exposure doses estimated for the song sparrow are presented in Table 3-14.

## 4.0 ECOLOGICAL EFFECTS CHARACTERIZATION

In the ecological effects characterization, information on the toxicity of the chemicals of potential concern to ecological receptors is presented. The toxicity information is used in the development of reference toxicity values (RTVs) (*i.e.*, acceptable daily doses or media concentrations) for selected indicator species. A comprehensive literature and database search was performed to identify relevant toxicological data for the receptors. The data sources that were reviewed included:

- Toxline.
- Registry of Toxic Effects of Chemical Substances (RTECS).
- Chemical Abstracts (CA Service).
- Integrated Risk Information System (IRIS).
- Hazardous Substances Data Base (HSDB).
- Phytotox.

In addition to these databases, toxicity information was obtained from a variety of primary literature sources as presented throughout the following subsections.

Species-specific toxicity data for indicator wildlife species often were not available for the chemicals of potential concern. Thus, where possible, toxicity values from the literature were selected using the most closely related species. Data for chronic toxicity were preferentially used, when available. Toxicity values selected for the assessment were the lowest exposure doses reported to be toxic or the highest doses associated with no adverse effect. If a dose reported to be toxic was used as the basis of the RTV, it was extrapolated to a no effect dose. Also, toxicity data reported as parts per million (ppm) in the diet were converted to a mg/kg body weight/day intake using data presented in the study, where available, or information on average ingestion rates and body weights of test animals. In addition, when toxicity data were not available for a specific substance, toxicity data from related isomers were used.

## Table 3−14

## Exposure Doses Estimated for the Song Sparrow (mg/kg−day)

| | Soil Ingestion Dose | | Seed Ingestion Dose | | Total Dose | |
|---|---|---|---|---|---|---|
| Chemical | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 4.34E−03 | 1.46E−02 | 4.15E−01 | 1.40E+00 | 4.19E−01 | 1.42E+00 |
| DDD | 6.26E−04 | 2.13E−03 | 8.38E−04 | 2.85E−03 | 1.46E−03 | 4.98E−03 |
| DDE | 1.46E−03 | 6.67E−03 | 3.15E−03 | 1.44E−02 | 4.60E−03 | 2.11E−02 |
| DDT | 2.08E−03 | 1.20E−02 | 1.20E−02 | 6.91E−02 | 1.41E−02 | 8.10E−02 |
| Dieldrin | 8.90E−05 | 2.51E−04 | 3.10E−03 | 8.74E−03 | 3.19E−03 | 8.99E−03 |
| Endrin | 7.01E−04 | 1.30E−03 | 2.44E−02 | 4.52E−02 | 2.51E−02 | 4.65E−02 |
| PAHs (total) | 5.93E−02 | 1.46E−01 | 2.83E−01 | 5.24E−01 | 3.43E−01 | 6.69E−01 |
| Benzo(a)anthracene | 6.05E−03 | 2.03E−02 | 1.34E−02 | 4.49E−02 | 1.94E−02 | 6.53E−02 |
| Benzo(a)pyrene | 6.80E−03 | 9.42E−03 | 1.20E−01 | 1.67E−01 | 1.27E−01 | 1.76E−01 |
| Benzo(b)fluoranthene | 4.47E−03 | 1.02E−02 | 5.45E−03 | 1.25E−02 | 9.91E−03 | 2.27E−02 |
| Benzo(g,h,i)perylene | 3.97E−03 | 1.15E−02 | 2.65E−03 | 7.70E−03 | 6.63E−03 | 1.92E−02 |
| Benzo(k)fluoranthene | 5.97E−03 | 1.57E−02 | 7.28E−03 | 1.92E−02 | 1.33E−02 | 3.49E−02 |
| Chrysene | 6.13E−03 | 3.40E−02 | 1.35E−02 | 7.52E−02 | 1.97E−02 | 1.09E−01 |
| Dibenz(a,h)anthracene | 9.74E−04 | 1.21E−03 | 1.33E−03 | 1.65E−03 | 2.31E−03 | 2.86E−03 |
| Fluoranthene | 9.27E−03 | 1.44E−02 | 5.28E−02 | 8.21E−02 | 6.21E−02 | 9.65E−02 |
| Indeno(1,2,3−cd)pyrene | 4.85E−03 | 1.06E−02 | 3.24E−03 | 7.09E−03 | 8.10E−03 | 1.77E−02 |
| Pyrene | 1.08E−02 | 1.82E−02 | 6.33E−02 | 1.06E−01 | 7.42E−02 | 1.25E−01 |
| PCB (Aroclor 1260) | 8.18E−04 | 1.29E−03 | 9.32E−04 | 1.47E−03 | 1.75E−03 | 2.76E−03 |
| **Inorganics** | | | | | | |
| Arsenic | 3.61E−02 | 4.39E−02 | 2.17E−02 | 2.63E−02 | 5.77E−02 | 7.02E−02 |
| Cadmium | 1.80E−03 | 2.10E−03 | 2.69E−02 | 3.15E−02 | 2.87E−02 | 3.36E−02 |
| Chromium | 6.23E−02 | 6.96E−02 | 2.80E−02 | 3.13E−02 | 9.03E−02 | 1.01E−01 |
| Copper | 2.60E−01 | 2.62E−01 | 6.49E+00 | 6.56E+00 | 6.75E+00 | 6.82E+00 |
| Lead | 5.53E−01 | 7.55E−01 | 4.98E−01 | 6.80E−01 | 1.05E+00 | 1.44E+00 |
| Manganese | 1.01E+00 | 1.14E+00 | 5.06E+00 | 5.72E+00 | 6.08E+00 | 6.87E+00 |
| Nickel | 7.43E−02 | 8.77E−02 | 4.46E−01 | 5.27E−01 | 5.20E−01 | 6.14E−01 |
| Zinc | 3.58E−01 | 4.08E−01 | 3.22E+01 | 3.67E+01 | 3.26E+01 | 3.71E+01 |

## 4.1 Toxicity to Terrestrial Wildlife

Since toxicity data for terrestrial wildlife are not nearly as complete as that found for laboratory and aquatic species, extrapolation of toxicity data from other animal studies is often necessary. Because of the uncertainty associated with these extrapolations, safety factors are applied to toxicological data to derive RTVs. The approach taken to derive RTVs for this study is provided in Table 4-1.

For those chemicals for which only acute lethality values were available, toxicity values for this assessment were derived by dividing the acute toxicity value by the appropriate safety factors. Based upon the guidance provided by the EPA (1986), a median lethal dose ($LD_{50}$) may be extrapolated to an acute toxicity threshold by dividing the $LD_{50}$ by a safety factor of 5. This safety factor is based on an analysis of dose-response data for pesticides. A dose-response 5 times lower than the $LD_{50}$ would be expected to result in a mortality rate of about 0.1% under typical conditions, and up to 10% when the responses in the test population are highly variable. Protection of 90 to 99% of a population is expected to provide an adequate margin of safety. Acute values were not extrapolated to chronic values.

A safety factor of 5 was applied in the extrapolation of a chronic lowest-observable-adverse-effect-level (LOAEL) to a chronic no-observable-adverse-effect-level (NOAEL). Weil and McCollister (1963) examined ratios of LOAELs to NOAELs from chronic and subchronic studies. Their analysis showed that 96% (50 out of 52) of the ratios were less than or equal to 5 (Lewis et al., 1990).

A safety factor of 5 was also applied when the test species differed from the indicator species selected for the site, since animal species can exhibit differences in sensitivity to a chemical (EPA, 1991b). Chemical-specific toxicity data for the indicator species were not found in the literature. Rather, short-tailed shrew and white-footed mouse RTVs for the constituents of concern were extrapolated from other mammalian studies, and robin and song sparrow RTVs were extrapolated from other avian studies, preferably using data from species with similar diets and digestive systems. Most of the available RTVs are based on

**Table 4-1**

**Safety Factors Used to Derive Reference Toxicity Values for Terrestrial Target Organisms**

| Available Toxicity Endpoint | Target Toxicity Endpoint | Safety Factor |
|---|---|---|
| Acute Lethality (i.e., $LD_{50}$) | Acute Toxicity Threshold | 5 |
| Chronic LOAEL | Chronic NOAEL | 5 |
| Within Phylogenetic Class Sensitivity (i.e., different species but same class) | Target Species Toxicity | 5 |

For example, in developing a reference toxicity value for a short-tailed shrew when the only data available is a chronic LOAEL for a rat, the following steps would be taken:

Rat chronic LOAEL for Compound X = 500 mg/kg.

(1) Chronic LOAEL → Chronic NOAEL $\frac{500 \text{ mg/kg}}{5} = 100 \text{ mg/kg}$

(2) Within Phylogenetic Class → Target Species RTV $\frac{100 \text{ mg/kg}}{5} = 20 \text{ mg/kg}$

effects in common laboratory species (*e.g.*, rats, mice, quail).

Using this methodology, the estimated RTVs for the Northern short-tailed shrew and the white-footed mouse are the same, and the estimated RTVs for the robin and song sparrow are the same. The RTVs for the mammalian and avian species are presented in Tables 4-2 and 4-3, respectively, along with the toxicity data used to calculate the RTVs.

### 4.2 Toxicity to Terrestrial Vegetation

There is currently no EPA guidance for quantitatively evaluating potential adverse effects to plants growing in contaminated soils. For this assessment, the phytotoxic potential of site-related chemicals was evaluated by comparing soil concentrations at the site to growth medium concentrations reported in the literature to cause adverse effects in plants Soil concentrations that did not result in any toxic effects in plants were also used as a basis of comparison, when available. Plant toxicity data are presented in Table 4-4.

### 4.3 Toxicity to Soil Invertebrates

There is currently no EPA guidance for quantitatively evaluating potential adverse effects to soil invertebrates inhabiting contaminated soils. For this assessment, potential toxicity to soil invertebrates from exposure to site-related chemicals was evaluated by comparing the site-specific soil concentrations to the soil concentrations reported in the literature to cause adverse effects to soil invertebrates. Soil invertebrate toxicity data are presented in Table 4-5.

## Table 4-2

## Basis of the Mammalian Reference Toxicity Values (RTVs) (mg/kg-day)

| Chemical | Species | Toxicity Endpoint | Effect | Dose (mg/kg-day) | Reference | Applied Safety Factor | Mammalian RTVs (mg/kg-day) |
|---|---|---|---|---|---|---|---|
| **Organics** | | | | | | | |
| Chlordane | Mouse | Chronic NOAEL | No significant liver lesions | 6.50E-01 | Khasawinah and Grutsch, 1989 | 5 | 1.3E-01 |
| DDD | Rat | Chronic Effect Dose | Decreased organ/body weight;suppressed immunity | 1.21E+02 | Hamid et al., 1974 | 25 | 4.8E+00 |
| DDE | Rat | Chronic Effect Dose | Mortality associated with tumor growth | 2.19E+01 | NCI, 1978 | 25 | 8.8E-01 |
| DDT | Rat | Chronic NOAEL | No growth effect on pups | 1.00E+00 | Clement and Okey, 1974 | 5 | 2.0E-01 |
| Endrin | Rat | Chronic NOAEL | No significant mortality | 2.50E-01 | Treon et al., 1955 | 5 | 5.0E-02 |
| PAHs[a] | Mouse | Chronic No Effect Dose | No effect on reproduction/fertility | 1.30E+02 | Rigdon and Neal, 1965 | 5 | 2.6E+01 |
| PCBs (Aroclor 1260) | Rat | Chronic NOAEL | No reproductive effect | 6.90E+00 | Linder et al., 1974 | 5 | 1.4E+00 |
| **Inorganics** | | | | | | | |
| Arsenic | Mouse | Chronic Effect Dose | Decreased survival in males | 9.50E-01 | Schroeder and Balassa, 1967 | 25 | 3.8E-02 |
| Cadmium | Rat | Chronic NOAEL | No effect on motor or kidney function | 1.64E+00 | Kotsonis and Klaassen, 1978 | 5 | 3.3E-01 |

## Table 4-2 (cont'd.)

## Basis of the Mammalian Reference Toxicity Values (RTVs) (mg/kg-day)

| Chemical | Species | Toxicity Endpoint | Effect | Dose (mg/kg-day) | Reference | Applied Safety Factor | Mammalian RTVs (mg/kg-day) |
|---|---|---|---|---|---|---|---|
| Chromium | Mouse | Chronic Effect Dose | Decreased spermatogenesis | 4.57E+00 | Zahid et al., 1990 | 25 | 1.8E-01 |
| Copper | Mouse | Chronic NOAEL | No reproductive effects | 2.60E+02 | Lecyk, 1980 | 5 | 5.2E+01 |
| Lead | Rat | Chronic NOAEL | No depressed immunity | 4.60E+00 | Luster et al., 1978 | 5 | 9.2E-01 |
| Manganese | Rat | Chronic Effect Dose | Motor ability, aggressive behavior | 1.40E+02 | Chandra, 1983 | 25 | 5.6E+00 |
| Nickel | Rat | Chronic Effect Dose | Increased number of young deaths and runts | 7.00E-01 | Schroeder and Mitchener, 1971 | 25 | 2.8E-02 |
| Zinc | Rat | Chronic NOAEL | No reproductive effects | 1.00E+02 | Schlicker and Cox, 1968 | 5 | 2.0E+01 |

NOAEL - No-observable-adverse-effect-level.
[a]This data is based on benzo(a)pyrene. The RTV for benzo(a)pyrene was applied to all PAHs.

## Table 4-3

**Basis of the Avian Reference Toxicity Values (RTVs) (mg/kg-day)**

| Chemical | Species | Toxicity Endpoint | Effect | Dose (mg/kg-day) | Reference | Applied Safety Factor | Avian RTV (mg/kg-day) |
|---|---|---|---|---|---|---|---|
| **Organics** | | | | | | | |
| Chlordane | Bobwhite (chick) | Acute $LC_{50}$ | 50% mortality | 5.20E+01 | Heath et al., 1972 | 25 | 2.1E+00 |
| DDD | Ring-necked pheasant | Acute $LC_{50}$ | 50% mortality | 5.90E+01 | Hill et al., 1975 | 25 | 2.4E+00 |
| DDE | Black duck | Chronic Effect Dose | Eggshell thinning and cracking, decreased duckling survival | 5.60E-01 | Longcore et al., 1971 | 25 | 2.2E-02 |
| DDT | Mallard (adult) | Chronic NOAEL | No eggshell thinning | 1.85E-01 | Davison and Sell, 1974 | 5 | 3.7E-02 |
| Endrin | Mallard | Chronic NOAEL | No reproductive effects | 1.20E-01 | Heath et al., 1972 | 5 | 2.4E-02 |
| PAHs | NDA | | | | | | |
| PCBs (Aroclor 1260) | Bobwhite (chick) | Acute $LC_{50}$ | 50% mortality | 1.17E+02 | Heath et al., 1972 | 25 | 4.7E+00 |
| **Inorganics** | | | | | | | |
| Arsenic | Mallard (1-day old) | Chronic NOAEL | No significant behavioral effects | 2.89E+01 | Whitworth et al., 1991 | 5 | 5.8E+00 |

**Table 4-3 (cont'd.)**

**Basis of the Avian Reference Toxicity Values (RTVs) (mg/kg-day)**

| Chemical | Species | Toxicity Endpoint | Effect | Dose (mg/kg-day) | Reference | Applied Safety Factor | Avian RTV (mg/kg-day) |
|---|---|---|---|---|---|---|---|
| Cadmium | Mallard | Chronic LOAEL | Egg production suppression | 2.00E+01 | White and Finley, 1978 | 25 | 8.0E-01 |
| Chromium | Chicks (3-week old) | Chronic NOAEL | No effects on body weight or mortality | 9.52E+01 | Hill and Matrone, 1970 | 5 | 1.9E+01 |
| Copper | Chicks (1-day old) | Chronic NOAEL | No significant mortality | 5.60E+01 | Mehring et al., 1960 | 5 | 1.1E+01 |
| Lead | Japanese quail (chicks) | Chronic NOAEL | No anemia, no depressed growth | 2.60E+01 | Morgan et al., 1975 | 5 | 5.2E+00 |
| Manganese | Turkey poults | Acute NOAEL | No deleterious effects | 2.29E+02 | Vohra and Kratzer, 1968 | 5 | 4.6E+01 |
| Nickel | Chicks (1-day old) | Acute NOAEL | No depressed weight gain | 1.69E+01 | Weber and Reid, 1968 | 5 | 3.4E+00 |
| Zinc | Chicks (1-day old) | Chronic NOAEL | No effects | 2.53E+02 | Oh et al., 1979 | 5 | 5.1E+01 |

NDA - No Data Available
NOAEL - No-observable-adverse-effect-level
LOAEL - Lowest-observable-adverse-effect-level

## Table 4–4

### Phytotoxicity Values for the Chemicals of Potential Concern

| Chemical | Plant Species | Treatment Duration | Media | Concentration (mg/kg) | Effects Measured | References | Comments |
|---|---|---|---|---|---|---|---|
| *ORGANICS* | | | | | | | |
| CHLORDANE (TOTAL) | grass | 1 month | growth medium | 32.5 | 95% decrease in germination | Phytotox Database (Juska, FV, 1961) | secondary source; converted from units of lb/acre |
| 4,4'–DDD | NDA | | | | | | |
| 4,4'–DDE | NDA | | | | | | |
| 4,4'–DDT | bean | not given | growth medium | 38.5 | no injury to shoots, incr. in # of roots | Phytotox Database (Fults & Payne, 1947) | secondary source; converted from units of lb/acre |
| 4,4'–DDT | chrysanthemum | not given | aqueous sol. | 2000 mg/L | no effect on plant | Phytotox Database (Dennis, EB.., 1963) | secondary source, mature roots soaked |
| DIELDRIN | eggplant/cabbage | 35 days | growth medium | 0.31 | shoot mass increase, root mass decrease | Phytotox Database (Kabir & Khan, 1972) | secondary source; converted from units of lb/acre |
| DIELDRIN | corn | 2 weeks | growth medium | 1.149 | plant size decrease | Phytotox Database (Cole et al., 1976) | secondary source; converted from units of lb/acre |
| DIELDRIN | cotton | 1–5 hours | aqueous sol. | 2,000 mg/L | decreased germination (77%) and growth | Eid et al., 1971 | lowest of 3 conc. tested (LEC), seeds were soaked |
| DIELDRIN | cotton | 1–5 hours | aqueous sol. | 10,000 mg/L | 98% avg decrease in germination | Eid et al., 1971 | second highest conc. tested, seeds were soaked |
| DIELDRIN | corn | 1–5 hour | aqueous sol. | 2,000 mg/L | 14% avg decrease in seed germination | Eid et al., 1971 | lowest of 3 conc. tested, seeds were soaked |
| DIELDRIN | corn | 1–5 hour | aqueous sol. | 10,000 mg/L | 64% decrease in seed germination | Eid et al., 1971 | second highest conc. tested, seeds were soaked |
| ENDRIN | NDA | | | | | | |
| PAHS | | | | | | | |
| BENZO(A) ANTHRACENE | NDA | | | | | | |
| BENZO(A) PYRENE | NDA | | | | | | |
| BENZO(B) FLUORANTHENE | NDA | | | | | | |
| BENZO(G,H,I) PERYLENE | NDA | | | | | | |
| BENZO(K) FLUORANTHENE | NDA | | | | | | |
| CHRYSENE | NDA | | | | | | |
| DIBENZO(A,H) ANTHRACENE | NDA | | | | | | |
| FLUORANTHENE | NDA | | | | | | |
| INDENO(1,2,3–CD) PYRENE | NDA | | | | | | |
| PYRENE | NDA | | | | | | |
| PCBs (Aroclor–1260) | NDA | | | | | | |
| *INORGANICS* | | | | | | | |
| ARSENIC | Bermuda grass | 6 weeks | clay,loam,sand | 11–15 | no growth reduction | Weaver et al., 1984 | $As_2O_3$; media pH 7.6 (clay), 7.7 (loam), 4.7 (sand) |
| ARSENIC | Bermuda grass | 6 weeks | sand, silty loam | 46–50 | reduced yield | Weaver et al., 1984 | $As_2O_3$; media pH 7.7 (loam), 4.7 (sand) |
| ARSENIC | Bermuda grass | 6 weeks | clay | 49 | no growth reduction | Weaver et al., 1984 | $As_2O_3$; media pH 7.6 |
| ARSENIC | Bermuda grass | 6 weeks | sand, silty loam | 91–95 | prevented growth | Weaver et al., 1984 | $As_2O_3$; media pH 7.7 (loam), 4.7 (sand) |
| ARSENIC | Bermuda grass | 6 weeks | clay | 94 | reduced growth | Weaver et al., 1984 | $As_2O_3$; media pH 7.6 |
| ARSENIC | grass | not given | soil | 104 | crop yield 88% of control | Sheppard, 1992 | species of arsenic unknown, secondary source |
| ARSENIC | grass | not given | soil | 320 | crop very stunted | Sheppard, 1992 | species of arsenic unknown, secondary source |
| ARSENIC | oat | not given | sand, silty loam | 1000 | 100% Y.R. in shoots | EPA, 1987a (Woolson et al., 1973) | secondary source, media pH 5.5 |
| ARSENIC | corn | not given | silty clay loam | 1000 | 90% Y.R. in shoots | EPA, 1987a (Woolson et al., 1973) | secondary source, media pH 5.5 |
| ARSENIC | oat | not given | silty clay loam | 100 | 81% Y.R. in shoots | EPA, 1987a (Woolson et al., 1973) | secondary source, media pH 5.5 |
| ARSENIC | corn | not given | silty clay loam | 100 | 4% Y.R. in shoots | EPA, 1987a (Woolson et al., 1973) | secondary source, media pH 5.5 |
| ARSENIC | oat | not given | silty clay loam | 10 | 22% Y.R. in shoots | EPA, 1987a (Woolson et al., 1973) | secondary source, media pH 5.5 |
| ARSENIC | corn | not given | loamy sand | 10 | 6% Y.R. in shoots | EPA, 1987a (Woolson et al., 1973) | secondary source, media pH 6.2 |
| ARSENIC | pea | not given | sand | 100 | 91.9% Y.R. in seeds | EPA, 1987a (Steevens et al., 1972) | secondary source, media pH 5.5 |
| ARSENIC | pea | not given | sand | 45 | 39.9% Y.R. in seeds | EPA, 1987a (Steevens et al., 1972) | secondary source, media pH 5.5 |
| ARSENIC | pea | not given | sand | 27 | 2.8% yield increase in seeds | EPA, 1987a (Steevens et al., 1972) | secondary source, media pH 5.5 |
| ARSENIC | not specified | not given | surface soil | 50 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount |
| ARSENIC | not specified | not given | surface soil | 25 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| ARSENIC | not specified | not given | surface soil | 30 | "phytotoxically excessive" | Kabata..., 1984 (Pendias, 1979) | secondary source |
| ARSENIC | not specified | not given | surface soil | 20 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |

## Table 4–4 (cont'd.)

## Phytotoxicity Values for the Chemicals of Potential Concern

| Chemical | Plant Species | Treatment Duration | Media | Concentration (mg/kg) | Effects Measured | References | Comments |
|---|---|---|---|---|---|---|---|
| ARSENIC | not specified | not given | surface soil | 15 | "phytotoxically excessive" | Kabata.., 1984 (Kitagishi..., 1979) | secondary source |
| CADMIUM | soybean | not given | soil | 2.5 | growth retardation and leaf discoloration | Hammons et al., 1978 | represents min. conc, secondary source |
| CADMIUM | winter wheat | not given | soil | 2.5 | general growth retardation | Hammons et al., 1978 | represents min. conc, secondary source |
| CADMIUM | lettuce | not given | soil | 2.5 | general growth retardation | Hammons et al., 1978 | represents min. conc, secondary source |
| CADMIUM | pea | 95 days | soil | 40 | decrease in seed yield | Hammons et al., 1978 | lowest conc. tested (LEC), secondary source |
| CADMIUM | pea | 95 days | soil | 200 | decrease in pod, vine, and root yield | Hammons et al., 1978 | highest conc. tested, secondary source |
| CADMIUM | oat | 100 days | soil | 40 | decrease in grain yield | Hammons et al., 1978 | lowest conc. tested (LEC), secondary source |
| CADMIUM | lettuce | 35 days | soil | 200 | decrease in leaf yield | Hammons et al., 1978 | highest conc. tested, secondary source |
| CADMIUM | fern | not given | grwth medium | 2.7 | decrease in spore germination | Gupta and Devi, 1992 | EC50, *Pteris vittata* |
| CADMIUM | fern | not given | grwth medium | 1.7 | decrease in spore germination | Gupta and Devi, 1992 | EC50, *Adiantum lunulatum* |
| CADMIUM | fern | not given | grwth medium | 2.8 | decrease in spore germination | Gupta and Devi, 1992 | EC50, *Ampelopteris prolifera* |
| CADMIUM | alfalfa | not given | fine sndy loam | 250 | 21% to 72% Y.R. in tops | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| CADMIUM | alfalfa | not given | fine sndy loam | 125 | 0.7% to 56% yield increase in tops | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| CADMIUM | alfalfa | not given | fine sndy loam | 50 | 3.5% to 9.8% yield increase in tops | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| CADMIUM | 5 species | not given | silt loam | 200 | 10 to 98.5% Y.R. in leaves | EPA, 1987a (John, 1973) | secondary source, media pH 5.1; grains/veg. |
| CADMIUM | 5 species | not given | silt loam | 40 | 0 to 96% Y.R. in leaves | EPA, 1987a (John, 1973) | secondary source, media pH 5.1; grains/veg. |
| CADMIUM | 7 species | not given | sand | 30 | 10 to 90% Y.R. in shoots | EPA, 1987a (Miles & Parker, 1979) | secondary source, media pH 4.8;wildflwrs/grasses |
| CADMIUM | 7 species | not given | sand | 10 | 24% Y.I. to 78% Y.R. in shoots | EPA, 1987a (Miles & Parker, 1979) | secondary source, media pH 4.8;wildflwrs/grasses |
| CADMIUM | alfalfa | not given | sandy loam | 5 | 20% yield increase in tops | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| CADMIUM | alfalfa | not given | sandy loam | 5 | 16% Y.R. in shoots | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| CADMIUM | alfalfa | not given | sandy loam | 5 | 13.6% Y.R. in shoots | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| CADMIUM | not specified | not given | surface soil | 5 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount, with "special reservation" |
| CADMIUM | not specified | not given | surface soil | 8 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| CADMIUM | not specified | not given | surface soil | 5 | "phytotoxically excessive" | Kabata.., 1984 (Pendias, 1979) | secondary source |
| CADMIUM | not specified | not given | surface soil | 3 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |
| CHROMIUM | not specified | not given | surface soil | 100 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount |
| CHROMIUM | not specified | not given | surface soil | 75 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| CHROMIUM | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Pendias, 1979) | secondary source |
| CHROMIUM | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |
| COPPER | bush bean | 17 days | yolo loam | 500 | 83% Y.R. in leaves, 69% Y.R. in stems | EPA, 1987b (Wallace et al., 1977a) | secondary source |
| COPPER | bush bean | 17 days | yolo loam | 200 | 26% Y.R. in leaves, 14% Y.R. in stems | EPA, 1987b (Wallace et al., 1977a) | secondary source |
| COPPER | corn | 6 weeks | sandy loam | 150 | 61% to 68% Y.R. in above ground biomass | EPA, 1987b (Cunningham et al., 1975b) | secondary source |
| COPPER | rye | 6 weeks | sandy loam | 150 | 43% Y.R. in above ground biomass | EPA, 1987b (Cunningham et al., 1975b) | secondary source |
| COPPER | white clover | not given | sandy soil | 52 | 50% Y.R. in shoots | EPA, 1987b (Dijkshoorn et al., 1979) | secondary source |
| COPPER | onion | not given | sandy loam | 30 | 16% Y.R. in leaves | EPA, 1987b (Gildon and Tinker, 1983) | secondary source |
| COPPER | not specified | not given | soil | 100 | plant growth inhibition | EPA, 1987b | secondary source |
| COPPER | not specified | not given | surface soil | 100 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount |
| COPPER | not specified | not given | surface soil | 60 | excessive or upper threshold conc. | Kovalsky, 1974 | 15–60 ppm is range of normal regulation of funct. |
| COPPER | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| COPPER | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Pendias, 1979) | secondary source |
| COPPER | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |
| COPPER | not specified | not given | surface soil | 125 | "phytotoxically excessive" | Kabata.., 1984 (Kitagishi..., 1979) | secondary source |
| LEAD | ryegrass | not given | fine sndy loam | 250 | no Y.R. in tops | EPA, 1987a (Allinson & Dziaco, 1981) | secondary source, media pH 4.5–6.4 |
| LEAD | oat | not given | fine sndy loam | 250 | no Y.R. in seeds | EPA, 1987a (Allinson & Dziaco, 1981) | secondary source, media pH 4.5–6.4 |
| LEAD | alfalfa | not given | fine sndy loam | 250 | 6.7% Y.R. in tops (not significant) | EPA, 1987a (Taylor & Allinson, 1981) | secondary source, media pH 6.9 |
| LEAD | corn | not given | sandy loam | 250 | 41.7% Y.R. in shoots | EPA, 1987a (Miller et al., 1977) | secondary source, media pH 6.0 |

## Table 4–4 (cont'd.)

## Phytotoxicity Values for the Chemicals of Potential Concern

| Chemical | Plant Species | Treatment Duration | Media | Concentration (mg/kg) | Effects Measured | References | Comments |
|---|---|---|---|---|---|---|---|
| LEAD | not specified | not given | surface soil | 100 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount |
| LEAD | not specified | not given | surface soil | 200 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| LEAD | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Pendias, 1979) | secondary source |
| LEAD | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |
| LEAD | not specified | not given | surface soil | 400 | "phytotoxically excessive" | Kabata.., 1984 (Kitagishi..., 1979) | secondary source |
| MANGANESE | not specified | not given | surface soil | 3000 | excessive or upper threshold conc. | Kovalsky, 1974 | 400–3000 ppm is range of normal reg. of funct. |
| MANGANESE | not specified | not given | surface soil | 1500 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| NICKEL | not specified | not given | surface soil | 100 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount |
| NICKEL | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| NICKEL | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Pendias, 1979) | secondary source |
| NICKEL | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |
| NICKEL | not specified | not given | surface soil | 100 | "phytotoxically excessive" | Kabata.., 1984 (Kitagishi..., 1979) | secondary source |
| ZINC | corn | not given | fine sndy loam | 960 | 98.2% Y.R. in forage | EPA, 1987a (Mortvedt et al., 1975) | secondary source, media pH 5.5 |
| ZINC | corn | not given | fine sndy loam | 960 | 86.7% Y.R. in forage | EPA, 1987a (Mortvedt et al., 1975) | secondary source, media pH 7.0 |
| ZINC | alfalfa | not given | silt loam | 400 | 17% Y.R. in tops | EPA, 1987a (Boawn & Rasmussen, 1971) | secondary source, media pH 7.1 |
| ZINC | corn | not given | fine sndy loam | 240 | 49.1% Y.R. in forage | EPA, 1987a (Mortvedt et al., 1975) | secondary source, media pH 5.5 |
| ZINC | corn | not given | fine sndy loam | 240 | 5.0% Y.R. in forage | EPA, 1987a (Mortvedt et al., 1975) | secondary source, media pH 7.0 |
| ZINC | soybean | not given | silt loam | 196 | 0.6% to 82% Y.R. in leaves | EPA, 1987a (White & Chaney, 1980) | secondary source, media pH 5.5–6.3 |
| ZINC | lettuce | not given | silt loam | 180 | no Y.R. in tops | EPA, 1987a (Mitchell et al., 1978) | secondary source, media pH 7.5 |
| ZINC | corn | not given | fine sndy loam | 60 | no Y.R. in forage | EPA, 1987a (Mortvedt et al., 1975) | secondary source, media pH 5.5 |
| ZINC | corn | not given | fine sndy loam | 60 | yield increase in forage | EPA, 1987a (Mortvedt et al., 1975) | secondary source, media pH 7.0 |
| ZINC | not specified | not given | surface soil | 300 | "tolerable amount" | El–Bassam and Tietjen, 1977 | proposed amount |
| ZINC | not specified | not given | surface soil | 70 | excessive or upper threshold conc. | Kovalsky, 1974 | 30–70 ppm is range of normal regulation of funct. |
| ZINC | not specified | not given | surface soil | 400 | "phytotoxically excessive" | Kabata.., 1984 (Linzon, 1978) | secondary source |
| ZINC | not specified | not given | surface soil | 300 | "phytotoxically excessive" | Kabata.., 1984 (Pendias, 1979) | secondary source |
| ZINC | not specified | not given | surface soil | 300 | "phytotoxically excessive" | Kabata.., 1984 (Kloke, 1981) | secondary source |
| ZINC | not specified | not given | surface soil | 250 | "phytotoxically excessive" | Kabata.., 1984 (Kitagishi..., 1979) | secondary source |

( ) = Unavailable primary source
# = Number
conc. = Concentration
EC50 = Effect observed in 50% of organisms
funct. = functions
grwth = Growth
inc. = Increase
LEC = Lowest Effect Concentration
min. = minimum
NDA = No data available
NOEL = No Observed Effect Level
reg. = regulation
sndy = Sandy
sol. = Solution
Y.R. = Yield reduction
Y.I. = Yield increase

## Table 4-5

### Invertebrate Toxicity Values for the Chemicals of Potential Concern

| Contaminant | Species | Concentration in Soil mg/kg (Toxicity Value) | Duration | Author(s) | Notes |
|---|---|---|---|---|---|
| Chlordane | earthworm (*Lumbricus terrestris*) | 6.25 (LOEC) | 21 days | Cikutovic et al. 1993 | significant sperm-count depression, artificial soil mixture |
| DDE | earthworm (*Lumbricus terrestris*) | 1.5 | 6 weeks | Cathey, 1982 | significant changes in the epidermis shown by blisters and erythema of the clitellum; artificial soil; lowest dose tested |
| DDE | earthworm (*Lumbricus terrestris*) | 14 | 6 weeks | Cathey, 1982 | < 1% mortality; artificial soil |
| DDE | earthworm (*Lumbricus terrestris*) | 61 (LC50) | 6 weeks | Cathey, 1982 | artificial soil |
| DDT | Pauropoda | 30[a] (NOEC) | not listed | Edwards and Thompson, 1973 | forest |
| DDT | Chilopoda | 30[a] (NOEC) | not listed | Edwards and Thompson, 1973 | forest |
| DDT | Diplopoda | 30[a] (NOEC) | not listed | Edwards and Thompson, 1973 | forest |
| DDT | Symphyla | 30[a] (NOEC) | not listed | Edwards and Thompson, 1973 | forest |
| DDT | Symphyla | 45[a] | not listed | Edwards and Thompson, 1973 | arable soils, decreased number |
| DDT | Pauropoda | 83.4[a] | not listed | Edwards and Thompson, 1973 | fallow, decreased number |
| DDT | Chilopoda | 83.4[a] | not listed | Edwards and Thompson, 1973 | fallow, decreased number |
| DDT | Symphyla | 83.4[a] | not listed | Edwards and Thompson, 1973 | fallow, decreased number |
| DDT | earthworm | 190[a] | not listed | Edwards and Thompson, 1973 | field plots, decreased number |
| DDT | earthworm | 200[a] (NOEC) | not listed | Edwards and Thompson, 1973 | forest |
| DDT | earthworm | 450[a] (NOEC) | not listed | Edwards and Thompson, 1973 | ploughed pasture |

## Table 4-5 (cont'd.)

## Invertebrate Toxicity Values for the Chemicals of Potential Concern

| Contaminant | Species | Concentration in Soil mg/kg (Toxicity Value) | Duration | Author(s) | Notes |
|---|---|---|---|---|---|
| Dieldrin | earthworm *(Eisenia fetida)* | 150 (LOEC) | 8 weeks | Neuhauser and Callahan, 1990 | significant difference in mean final body weights |
| Dieldrin | earthworm *(Eisenia fetida)* | 25 (LOEC) | 8 weeks | Neuhauser and Callahan, 1990 | significant difference in total cocoon production/worm |
| Dieldrin | earthworm *(Eisenia fetida)* | 500 (LOEC) | 8 weeks | Neuhauser and Callahan, 1990 | death |
| Dieldrin | earthworm *(Eisenia fetida)* | 30 (LOEC) | 90 days | Venter and Reinecke, 1987 | increased incubation periods |
| Dieldrin | earthworm *(Eisenia fetida)* | 50 (LOEC) | 90 days | Venter and Reinecke, 1987 | decreased hatching success |
| Dieldrin | earthworm *Eisenia fetida)* | 100 (LOEC) | not listed | Venter and Reinecke, 1985 | delayed and retarded development of clitellum |
| Endrin | earthworm *(Lumbricus terrestris)* | 1.5 | 6 weeks | Cathey, 1982 | significant changes in the epidermis shown by blisters and erythema of the clitellum; artificial soil; lowest dose tested |
| Endrin | earthworm *(Lumbricus terrestris)* | 13 | 6 weeks | Cathey, 1982 | < 1% mortality; artificial soil |
| Endrin | earthworm *(Lumbricus terrestris)* | 66 (LC50) | 6 weeks | Cathey, 1982 | artificial soil |
| Benzo(a)pyrene | earthworm *(Eisenia foetida)* | >26,000 (LC50) | not listed | Cureton et al., 1994 | artificial soil |
| Cadmium | earthworm *(Eisenia foetida)* | 1843 (LC50) | 2 weeks | Neuhauser et al. 1986 | artificial soil mixture |
| Cadmium | earthworm *(Eisenia foetida)* | >300 (LC50) | 14 days | Spurgeon et al. 1994 | |
| Cadmium | earthworm *(Eisenia foetida)* | >300 (LC50) | 56 days | Spurgeon et al. 1994 | |
| Cadmium | earthworm *(Eisenia foetida)* | >300 (NOEC) | 56 days | Spurgeon et al. 1994 | mortality |
| Cadmium | earthworm *(Eisenia foetida)* | 46.3 (EC50) | 56 days | Spurgeon et al. 1994 | cocoon production |

## Table 4-5 (cont'd.)

## Invertebrate Toxicity Values for the Chemicals of Potential Concern

| Contaminant | Species | Concentration in Soil mg/kg (Toxicity Value) | Duration | Author(s) | Notes |
|---|---|---|---|---|---|
| Cadmium | earthworm *(Eisenia foetida)* | 39.2 (NOEC) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Cadmium | earthworm *(Eisenia andrei)* | >1000 (LC50) | 3 weeks | Van Gestel and Van Straalen, 1994 | artificial soil |
| Cadmium | earthworm *(Eisenia andrei)* | 100 (NOEC) | not listed | Van Gestel and Van Straalen, 1994 | body growth; artificial soil |
| Cadmium | earthworm *(Eisenia andrei)* | >10 (NOEC) | not listed | Van Gestel and Van Straalen, 1994 | reproduction; artificial soil |
| Cadmium | woodlouse *(Porcellio scaber)* | 100 [b] | 1 year | Hopkin and Hames 1994 | mortality before reproduction |
| Chromium | earthworm *(Eisenia andrei)* | >1000 (LC50) | 3 weeks | Van Gestel and Van Straalen, 1994 | artificial soil |
| Chromium | earthworm *(Eisenia andrei)* | 320 (NOEC) | not listed | Van Gestel and Van Straalen, 1994 | body growth; artificial soil |
| Chromium | earthworm *(Eisenia andrei)* | >32 (NOEC) | not listed | Van Gestel and Van Straalen, 1994 | reproduction; artificial soil |
| Copper | earthworm *(Eisenia foetida)* | 643 (LC50) | 2 weeks | Neuhauser et al. 1986 | artificial soil mixture |
| Copper | earthworm *(Eisenia foetida)* | 683 (LC50) | 14 days | Spurgeon et al. 1994 | |
| Copper | earthworm *(Eisenia foetida)* | 555 (LC50) | 56 days | Spurgeon et al. 1994 | |
| Copper | earthworm *(Eisenia foetida)* | 210 (NOEC) | 56 days | Spurgeon et al. 1994 | mortality |
| Copper | earthworm *(Eisenia foetida)* | 53.3 (EC50) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Copper | earthworm *(Eisenia foetida)* | 32 (NOEC) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Copper | woodlouse *(Porcellio scaber)* | 100 [b] | 1 year | Hopkin and Hames 1994 | mortality before reproduction |

## Table 4-5 (cont'd.)

## Invertebrate Toxicity Values for the Chemicals of Potential Concern

| Contaminant | Species | Concentration in Soil mg/kg (Toxicity Value) | Duration | Author(s) | Notes |
|---|---|---|---|---|---|
| Lead | earthworm *(Eisenia foetida)* | 5941 (LC50) | 2 weeks | Neuhauser et al. 1986 | artificial soil mixture |
| Lead | earthworm *(Eisenia foetida)* | 4480 (LC50) | 14 days | Spurgeon et al. 1994 | |
| Lead | earthworm *(Eisenia foetida)* | 3760 (LC50) | 56 days | Spurgeon et al. 1994 | |
| Lead | earthworm *(Eisenia foetida)* | 2190 (NOEC) | 56 days | Spurgeon et al. 1994 | mortality |
| Lead | earthworm *(Eisenia foetida)* | 1940 (EC50) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Lead | earthworm *(Eisenia foetida)* | 1810 (NOEC) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Lead | woodlouse *(Porcellio scaber)* | 2000 [b] | 1 year | Hopkin and Hames 1994 | mortality before reproduction |
| Nickel | earthworm *(Eisenia foetida)* | 757 (LC50) | 2 weeks | Neuhauser et al. 1986 | artificial soil mixture |
| Zinc | earthworm *(Eisenia foetida)* | 662 (LC50) | 2 weeks | Neuhauser et al. 1986 | artificial soil mixture |
| Zinc | earthworm *(Eisenia foetida)* | 1010 (LC50) | 14 days | Spurgeon et al. 1994 | |
| Zinc | earthworm *(Eisenia foetida)* | 745 (LC50) | 56 days | Spurgeon et al. 1994 | |
| Zinc | earthworm *(Eisenia foetida)* | 289 (NOEC) | 56 days | Spurgeon et al. 1994 | mortality |
| Zinc | earthworm *(Eisenia foetida)* | 276 (EC50) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Zinc | earthworm *(Eisenia foetida)* | 199 (NOEC) | 56 days | Spurgeon et al. 1994 | cocoon production |
| Zinc | woodlouse *(Porcellio scaber)* | 1000 [b] | 1 year | Hopkin and Hames 1994 | mortality before reproduction |
| Zinc | woodlouse *(Porcellio scaber)* | 5000 | not listed | Hopkin and Hames 1994 | secondary source; measured in field |

[a] Converted from kg/hectare assuming a bulk soil density of 1.5 $g/cm^3$ and a soil mixing depth for untilled soil of 1 cm (EPA, 1990b).

[b] Expressed as concentration in leaves (or food), not in soil.

## 5.0 RISK CHARACTERIZATION

### 5.1 General Approach

The potential risk posed to ecological receptors (shrew, mouse, robin, and sparrow) was assessed by comparing estimated daily doses with reference toxicity values. This comparison, described as a hazard quotient (HQ), was made for each chemical and is expressed as:

$$HQ = EDD/RTV_{ing}$$

Where:

$EDD$ = Estimated daily dose of a chemical through a specific exposure route (*i.e.*, soil ingestion or food ingestion) (mg/kg-day).

$RTV_{ing}$ = Reference toxicity value for the same chemical through the ingestion route (mg/kg-day).

It is important to note that this methodology is not a measure of and cannot be used to determine quantitative risk, *i.e.*, it does not predict the relative likelihood of adverse effects occurring. If the calculated hazard quotient (HQ) exceeds unity (*i.e.*, $>1$), then it simply indicates that the species of concern may be at risk to an adverse effect from the particular chemical or exposure route on which the HQ was calculated. Because reference toxicity values incorporate a number of safety factors, if a reference toxicity value is exceeded, *i.e.*, the hazard quotient exceeds unity, it does not necessarily indicate that an adverse effect will occur.

Exposures to the same chemical through multiple exposure routes are assumed to be cumulative. Consequently, a hazard index for a specific chemical ($HI_{chem}$) examines the potential for risk posed by a chemical through more than one exposure route, where applicable. For example, the cumulative hazard index for an individual chemical in all media was determined for the shrew as follows:

$$HI_{chem} = HQ_{worm} + HQ_{soil}$$

Where:

$HI_{chem}$ = Hazard index for a chemical.

$HQ_{worm}$ = Hazard quotient for the same chemical through ingestion of earthworms.

$HQ_{soil}$ = Hazard quotient for the same chemical through soil ingestion.

As with the hazard quotient, a chemical-specific hazard index greater than 1 does not necessarily indicate that an adverse effect will occur.

To assess the potential for adverse effects to occur to plants, soil chemical data was compared to phytotoxicity data available in the literature. Since phytotoxicity data is often not species-specific, or is available for plant species that are not present at the site, an HQ was not calculated. Rather, the phytotoxicity data, which were available for a variety of plant species, were compared to the soil chemical data.

Similarly, an HQ was not calculated for soil invertebrates. Since there is not a large toxicological database for invertebrates, available data are presented, and are directly compared to the soil chemical data.

The following is a discussion of the potential risks posed to terrestrial wildlife, plant life, and soil invertebrates for the chemicals of potential concern. The risk is specific to the previously presented exposure scenarios. Uncertainties associated with these risk estimates are discussed in Section 6.

## 5.2 Risk Characterization for Terrestrial Wildlife

### 5.2.1 Northern Short-Tailed Shrew

Potential risk to the short-tailed shrew was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-5) with the reference toxicity values derived for the shrew (Table 4-2). The resulting hazard indices for the shrew are presented in Table 5-1. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as well as the upper 95% confidence limit of the mean.

As shown in Table 5-1, the following chemicals exceeded a hazard index of one:

| Mean | Upper 95% Confidence Limit |
|---|---|
| • Chlordane (12) | • Chlordane (41) |
| • DDT (8) | • DDE (4.1) |
| • Endrin (3.7) | • DDT (46) |
| • Arsenic (10) | • Endrin (6.9) |
| • Cadmium (1.8) | • PCBs (1.5) |
| • Chromium (22) | • Arsenic (13) |
| • Lead (27) | • Cadmium (2.2) |
| • Manganese (2.8) | • Chromium (24) |
| • Nickel (360) | • Lead (37) |
| • Zinc (13) | • Manganese (3.1) |
| | • Nickel (430) |
| | • Zinc (15) |

Nickel had the highest hazard indices. The majority (84%-100%) of the hazard index for pesticides, PCBs, cadmium, chromium, lead, nickel, and zinc was due to earthworm ingestion, while the majority (68%) of the arsenic hazard index was due to soil ingestion. Manganese had approximately equal contributions to the hazard index from each exposure route.

The results show a potential for adverse effects to occur to insectivorous small mammals that feed at the site.

## Table 5-1

## Summary of Hazard Quotients/Indices for the Northern Short-Tailed Shrew

| Chemical | Hazard Quotient for Soil Ingestion | | Hazard Quotient for Earthworm Ingestion | | Chemical-Specific Hazard Indices | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 2.5E-01 | 8.4E-01 | 1.2E+01 | 4.0E+01 | 1.2E+01 | 4.1E+01 |
| DDD | 9.7E-04 | 3.3E-03 | 7.8E-02 | 2.6E-01 | 7.9E-02 | 2.7E-01 |
| DDE | 1.2E-02 | 5.6E-02 | 8.8E-01 | 4.0E+00 | 8.9E-01 | 4.1E+00 |
| DDT | 7.7E-02 | 4.5E-01 | 7.9E+00 | 4.6E+01 | 8.0E+00 | 4.6E+01 |
| Dieldrin | 1.0E-02 | 2.8E-02 | 9.6E-01 | 2.7E+00 | 9.7E-01 | 2.7E+00 |
| Endrin | 1.0E-01 | 1.9E-01 | 3.6E+00 | 6.7E+00 | 3.7E+00 | 6.9E+00 |
| PAHs (total) | 1.7E-02 | 4.2E-02 | 5.4E-02 | 1.3E-01 | 7.1E-02 | 1.8E-01 |
| Benzo(a)anthracene | 1.7E-03 | 5.8E-03 | 4.5E-03 | 1.5E-02 | 6.2E-03 | 2.1E-02 |
| Benzo(a)pyrene | 1.9E-03 | 2.7E-03 | 6.4E-03 | 8.9E-03 | 8.3E-03 | 1.2E-02 |
| Benzo(b)fluoranthene | 1.3E-03 | 2.9E-03 | 2.6E-03 | 5.9E-03 | 3.9E-03 | 8.9E-03 |
| Benzo(g,h,i)perylene | 1.1E-03 | 3.3E-03 | 1.6E-03 | 4.8E-03 | 2.8E-03 | 8.1E-03 |
| Benzo(k)fluoranthene | 1.7E-03 | 4.5E-03 | 3.5E-03 | 9.1E-03 | 5.2E-03 | 1.4E-02 |
| Chrysene | 1.8E-03 | 9.7E-03 | 7.5E-03 | 4.1E-02 | 9.2E-03 | 5.1E-02 |
| Dibenz(a,h)anthracene | 2.8E-04 | 3.5E-04 | 1.3E-03 | 1.6E-03 | 1.6E-03 | 2.0E-03 |
| Fluoranthene | 2.7E-03 | 4.1E-03 | 9.5E-03 | 1.5E-02 | 1.2E-02 | 1.9E-02 |
| Indeno(1,2,3-cd)pyrene | 1.4E-03 | 3.0E-03 | 5.5E-03 | 1.2E-02 | 6.9E-03 | 1.5E-02 |
| Pyrene | 3.1E-03 | 5.2E-03 | 1.2E-02 | 2.0E-02 | 1.5E-02 | 2.5E-02 |
| PCB (Aroclor 1260) | 4.4E-03 | 6.8E-03 | 9.2E-01 | 1.5E+00 | 9.3E-01 | 1.5E+00 |
| **Inorganics** | | | | | | |
| Arsenic | 7.1E+00 | 8.6E+00 | 3.3E+00 | 4.0E+00 | 1.0E+01 | 1.3E+01 |
| Cadmium | 4.1E-02 | 4.7E-02 | 1.8E+00 | 2.1E+00 | 1.8E+00 | 2.2E+00 |
| Chromium | 2.6E+00 | 2.9E+00 | 1.9E+01 | 2.1E+01 | 2.2E+01 | 2.4E+01 |
| Copper | 3.7E-02 | 3.8E-02 | 1.6E-01 | 1.6E-01 | 2.0E-01 | 2.0E-01 |
| Lead | 4.5E+00 | 6.1E+00 | 2.3E+01 | 3.1E+01 | 2.7E+01 | 3.7E+01 |
| Manganese | 1.3E+00 | 1.5E+00 | 1.4E+00 | 1.6E+00 | 2.8E+00 | 3.1E+00 |
| Nickel | 2.0E+01 | 2.3E+01 | 3.4E+02 | 4.1E+02 | 3.6E+02 | 4.3E+02 |
| Zinc | 1.3E-01 | 1.5E-01 | 1.3E+01 | 1.5E+01 | 1.3E+01 | 1.5E+01 |



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### 5.2.2 White-Footed Mouse

Potential risk to the white-footed mouse was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-8) with the reference toxicity values derived for the mouse (Table 4-2). The resulting hazard indices for the white-footed mouse are presented in Table 5-2. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as well as the upper 95% confidence limit of the mean.

As shown in Table 5-2, the following chemicals exceeded a hazard index of one:

| Mean | Upper 95% Confidence Limit |
|---|---|
| • Chlordane (2.4) | • Chlordane (8.3) |
| • Arsenic (1.9) | • Arsenic (2.3) |
| • Lead (1.3) | • Lead (1.8) |
| • Nickel (16) | • Manganese (1.1) |
| • Zinc (1.2) | • Nickel (19) |
| | • Zinc (1.4) |

Nickel and chlordane had the highest hazard indices. The hazard indices for most of the metals (arsenic, lead, manganese, and zinc) were just slightly above one. The majority (71%-98%) of the hazard index for chlordane, manganese, nickel, and zinc was due to seed ingestion, while the majority (69%-77%) of the arsenic and lead hazard indices was due to soil ingestion.

The results show a potential for adverse effects to occur to herbivorous small mammals that feed at the site.

### 5.2.3 American Robin

Potential risk to the robin was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-11) with the reference toxicity values derived for the robin (Table 4-3). The resulting hazard indices for the robin are presented in Table 5-3. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as

## Table 5–2

## Summary of Hazard Quotients/Indices for the White–footed Mouse

| Chemical | Hazard Quotient for Soil Ingestion | | Hazard Quotient for Seed Ingestion | | Chemical–Specific Hazard Indices | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 5.0E–02 | 1.7E–01 | 2.4E+00 | 8.1E+00 | 2.4E+00 | 8.3E+00 |
| DDD | 2.0E–04 | 6.7E–04 | 1.3E–04 | 4.5E–04 | 3.3E–04 | 1.1E–03 |
| DDE | 2.5E–03 | 1.1E–02 | 2.7E–03 | 1.2E–02 | 5.2E–03 | 2.4E–02 |
| DDT | 1.6E–02 | 9.0E–02 | 4.5E–02 | 2.6E–01 | 6.1E–02 | 3.5E–01 |
| Dieldrin | 2.0E–03 | 5.7E–03 | 3.5E–02 | 9.9E–02 | 3.7E–02 | 1.1E–01 |
| Endrin | 2.1E–02 | 3.9E–02 | 3.7E–01 | 6.8E–01 | 3.9E–01 | 7.2E–01 |
| PAHs (total) | 3.4E–03 | 8.4E–03 | 8.2E–03 | 1.5E–02 | 1.2E–02 | 2.4E–02 |
| Benzo(a)anthracene | 3.5E–04 | 1.2E–03 | 3.9E–04 | 1.3E–03 | 7.4E–04 | 2.5E–03 |
| Benzo(a)pyrene | 3.9E–04 | 5.4E–04 | 3.5E–03 | 4.8E–03 | 3.9E–03 | 5.4E–03 |
| Benzo(b)fluoranthene | 2.6E–04 | 5.9E–04 | 1.6E–04 | 3.6E–04 | 4.2E–04 | 9.5E–04 |
| Benzo(g,h,i)perylene | 2.3E–04 | 6.7E–04 | 7.7E–05 | 2.2E–04 | 3.1E–04 | 8.9E–04 |
| Benzo(k)fluoranthene | 3.5E–04 | 9.1E–04 | 2.1E–04 | 5.5E–04 | 5.6E–04 | 1.5E–03 |
| Chrysene | 3.5E–04 | 2.0E–03 | 3.9E–04 | 2.2E–03 | 7.5E–04 | 4.1E–03 |
| Dibenz(a,h)anthracene | 5.6E–05 | 7.0E–05 | 3.9E–05 | 4.8E–05 | 9.5E–05 | 1.2E–04 |
| Fluoranthene | 5.4E–04 | 8.3E–04 | 1.5E–03 | 2.4E–03 | 2.1E–03 | 3.2E–03 |
| Indeno(1,2,3–cd)pyrene | 2.8E–04 | 6.1E–04 | 9.4E–05 | 2.0E–04 | 3.7E–04 | 8.2E–04 |
| Pyrene | 6.3E–04 | 1.1E–03 | 1.8E–03 | 3.1E–03 | 2.5E–03 | 4.1E–03 |
| PCB (Aroclor 1260) | 8.8E–04 | 1.4E–03 | 5.0E–04 | 7.9E–04 | 1.4E–03 | 2.2E–03 |
| **Inorganics** | | | | | | |
| Arsenic | 1.4E+00 | 1.7E+00 | 4.3E–01 | 5.2E–01 | 1.9E+00 | 2.3E+00 |
| Cadmium | 8.2E–03 | 9.6E–03 | 6.1E–02 | 7.2E–02 | 7.0E–02 | 8.1E–02 |
| Chromium | 5.2E–01 | 5.8E–01 | 1.2E–01 | 1.3E–01 | 6.4E–01 | 7.1E–01 |
| Copper | 7.5E–03 | 7.6E–03 | 9.4E–02 | 9.5E–02 | 1.0E–01 | 1.0E–01 |
| Lead | 9.0E–01 | 1.2E+00 | 4.1E–01 | 5.6E–01 | 1.3E+00 | 1.8E+00 |
| Manganese | 2.7E–01 | 3.1E–01 | 6.8E–01 | 7.7E–01 | 9.5E–01 | 1.1E+00 |
| Nickel | 4.0E+00 | 4.7E+00 | 1.2E+01 | 1.4E+01 | 1.6E+01 | 1.9E+01 |
| Zinc | 2.7E–02 | 3.1E–02 | 1.2E+00 | 1.4E+00 | 1.2E+00 | 1.4E+00 |

## Table 5–3

## Summary of Hazard Quotients/Indices for the American Robin

| Chemical | Hazard Quotient for Soil Ingestion | | Hazard Quotient for Earthworm Ingestion | | Chemical–Specific Hazard Indices | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 1.8E–02 | 5.9E–02 | 8.3E–01 | 2.8E+00 | 8.4E–01 | 2.8E+00 |
| DDD | 2.2E–03 | 7.5E–03 | 1.7E–01 | 5.9E–01 | 1.8E–01 | 6.0E–01 |
| DDE | 5.6E–01 | 2.6E+00 | 3.9E+01 | 1.8E+02 | 4.0E+01 | 1.8E+02 |
| DDT | 4.8E–01 | 2.8E+00 | 4.8E+01 | 2.7E+02 | 4.8E+01 | 2.8E+02 |
| Dieldrin | 3.2E–03 | 8.9E–03 | 2.9E–01 | 8.3E–01 | 3.0E–01 | 8.4E–01 |
| Endrin | 2.5E–01 | 4.6E–01 | 8.4E+00 | 1.6E+01 | 8.7E+00 | 1.6E+01 |
| PAHs (total) | NC | NC | NC | NC | NC | NC |
| Benzo(a)anthracene | NC | NC | NC | NC | NC | NC |
| Benzo(a)pyrene | NC | NC | NC | NC | NC | NC |
| Benzo(b)fluoranthene | NC | NC | NC | NC | NC | NC |
| Benzo(g,h,i)perylene | NC | NC | NC | NC | NC | NC |
| Benzo(k)fluoranthene | NC | NC | NC | NC | NC | NC |
| Chrysene | NC | NC | NC | NC | NC | NC |
| Dibenz(a,h)anthracene | NC | NC | NC | NC | NC | NC |
| Fluoranthene | NC | NC | NC | NC | NC | NC |
| Indeno(1,2,3–cd)pyrene | NC | NC | NC | NC | NC | NC |
| Pyrene | NC | NC | NC | NC | NC | NC |
| PCB (Aroclor 1260) | 1.5E–03 | 2.3E–03 | 3.1E–01 | 4.8E–01 | 3.1E–01 | 4.8E–01 |
| **Inorganics** | | | | | | |
| Arsenic | 5.3E–02 | 6.4E–02 | 2.4E–02 | 2.9E–02 | 7.7E–02 | 9.3E–02 |
| Cadmium | 1.9E–02 | 2.2E–02 | 8.3E–01 | 9.7E–01 | 8.5E–01 | 9.9E–01 |
| Chromium | 2.8E–02 | 3.1E–02 | 2.0E–01 | 2.3E–01 | 2.3E–01 | 2.6E–01 |
| Copper | 2.0E–01 | 2.0E–01 | 8.3E–01 | 8.4E–01 | 1.0E+00 | 1.0E+00 |
| Lead | 9.0E–01 | 1.2E+00 | 4.5E+00 | 6.2E+00 | 5.4E+00 | 7.4E+00 |
| Manganese | 1.9E–01 | 2.1E–01 | 1.9E–01 | 2.2E–01 | 3.8E–01 | 4.3E–01 |
| Nickel | 1.9E–01 | 2.2E–01 | 3.1E+00 | 3.7E+00 | 3.3E+00 | 3.9E+00 |
| Zinc | 6.0E–02 | 6.8E–02 | 5.6E+00 | 6.3E+00 | 5.6E+00 | 6.4E+00 |

NC – Could not be calculated

well as the upper 95% confidence limit of the mean. The hazard indices presented for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, since only acute toxicity data were available for deriving the RTVs. The hazard indices for all other chemicals are based on chronic endpoints.

As shown in Table 5-3, the following chemicals exceeded a hazard index of one:

| Mean | Upper 95% Confidence Limit |
|---|---|
| • DDE (40) | • Chlordane (2.8) |
| • DDT (48) | • DDE (180) |
| • Endrin (8.7) | • DDT (280) |
| • Lead (5.4) | • Endrin (16) |
| • Nickel (3.3) | • Lead (7.4) |
| • Zinc (5.6) | • Nickel (3.9) |
| | • Zinc (6.4) |

DDE and DDT had the highest hazard indices. The majority (83%-99%) of the hazard index for these contaminants of concern can be attributed to earthworm ingestion. Note the potential for acute risk to the robin due to chlordane in soil.

The results show a potential for adverse effects to occur to omnivorous passerines that feed at the site.

### 5.2.4 Song Sparrow

Potential risk to the song sparrow was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-14) with the reference toxicity values derived for the song sparrow (Table 4-3). The resulting hazard indices for the song sparrow are presented in Table 5-4. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as well as the upper 95% confidence limit of the mean. The hazard indices presented for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, since only acute toxicity data were available for deriving the RTVs. The hazard indices for all other chemicals are based on chronic endpoints.

## Table 5-4

### Summary of Hazard Quotients/Indices for the Song Sparrow

| Chemical | Hazard Quotient for Soil Ingestion | | Hazard Quotient for Seed Ingestion | | Chemical-Specific Hazard Indices | |
|---|---|---|---|---|---|---|
| | Mean | 95% UCL | Mean | 95% UCL | Mean | 95% UCL |
| **Organics** | | | | | | |
| Chlordane | 2.1E-03 | 7.0E-03 | 2.0E-01 | 6.7E-01 | 2.0E-01 | 6.7E-01 |
| DDD | 2.6E-04 | 8.9E-04 | 3.5E-04 | 1.2E-03 | 6.1E-04 | 2.1E-03 |
| DDE | 6.6E-02 | 3.0E-01 | 1.4E-01 | 6.6E-01 | 2.1E-01 | 9.6E-01 |
| DDT | 5.6E-02 | 3.2E-01 | 3.2E-01 | 1.9E+00 | 3.8E-01 | 2.2E+00 |
| Dieldrin | 3.7E-04 | 1.0E-03 | 1.3E-02 | 3.6E-02 | 1.3E-02 | 3.7E-02 |
| Endrin | 2.9E-02 | 5.4E-02 | 1.0E+00 | 1.9E+00 | 1.0E+00 | 1.9E+00 |
| PAHs (total) | NC | NC | NC | NC | NC | NC |
| Benzo(a)anthracene | NC | NC | NC | NC | NC | NC |
| Benzo(a)pyrene | NC | NC | NC | NC | NC | NC |
| Benzo(b)fluoranthene | NC | NC | NC | NC | NC | NC |
| Benzo(g,h,i)perylene | NC | NC | NC | NC | NC | NC |
| Benzo(k)fluoranthene | NC | NC | NC | NC | NC | NC |
| Chrysene | NC | NC | NC | NC | NC | NC |
| Dibenz(a,h)anthracene | NC | NC | NC | NC | NC | NC |
| Fluoranthene | NC | NC | NC | NC | NC | NC |
| Indeno(1,2,3-cd)pyrene | NC | NC | NC | NC | NC | NC |
| Pyrene | NC | NC | NC | NC | NC | NC |
| PCB (Aroclor 1260) | 1.7E-04 | 2.7E-04 | 2.0E-04 | 3.1E-04 | 3.7E-04 | 5.9E-04 |
| **Inorganics** | | | | | | |
| Arsenic | 6.2E-03 | 7.6E-03 | 3.7E-03 | 4.5E-03 | 1.0E-02 | 1.2E-02 |
| Cadmium | 2.2E-03 | 2.6E-03 | 3.4E-02 | 3.9E-02 | 3.6E-02 | 4.2E-02 |
| Chromium | 3.3E-03 | 3.7E-03 | 1.5E-03 | 1.6E-03 | 4.8E-03 | 5.3E-03 |
| Copper | 2.4E-02 | 2.4E-02 | 5.9E-01 | 6.0E-01 | 6.1E-01 | 6.2E-01 |
| Lead | 1.1E-01 | 1.5E-01 | 9.6E-02 | 1.3E-01 | 2.0E-01 | 2.8E-01 |
| Manganese | 2.2E-02 | 2.5E-02 | 1.1E-01 | 1.2E-01 | 1.3E-01 | 1.5E-01 |
| Nickel | 2.2E-02 | 2.6E-02 | 1.3E-01 | 1.5E-01 | 1.5E-01 | 1.8E-01 |
| Zinc | 7.0E-03 | 8.0E-03 | 6.3E-01 | 7.2E-01 | 6.4E-01 | 7.3E-01 |

NC - Could not be calculated

As shown in Table 5-4, none of the chemicals exceeded a hazard index of one based on the mean concentrations, and only two chemicals slightly exceeded a hazard index of one based on the upper 95% confidence limit of the mean - DDT (2.2) and Endrin (1.9).

The results show that there is very little potential for adverse effects to occur to seed-eating passerines that feed at the site. However, the potential for chronic effects to occur from exposure to chlordane, DDD, PAHs, PCBs, manganese, and nickel could not be evaluated.

### 5.3 Risk Characterization for Terrestrial Vegetation

Potential effects to terrestrial plants at the site were assessed by comparing soil concentrations to available phytotoxicity data (Table 4-4). There were very little phytotoxicity data available for the organic chemicals. A much greater amount of phytotoxicity data were available for the inorganics. Exceedances of phytotoxicity data occurred for arsenic, cadmium, copper, lead, and zinc. Arsenic soil concentrations at a number of locations at the site exceeded levels at which yield reductions have been reported in the literature, and exceeded "phytotoxically excessive" concentrations as reported by Kabata-Pendias and Pendias (1984). However, all arsenic concentrations fell below the concentration reported as a "tolerable amount" by El-Bassam and Tietjen (1977). The maximum detected value of cadmium in the vicinity of the propellant storage area at the site (sample location 16SS01) exceeded the concentration reported to cause growth retardation and leaf discoloration. Also, cadmium concentrations at two locations at the site (16SS01, 14SUB01) exceeded concentrations reported in the literature to reduce spore germination in ferns. There are a number of locations at the site where copper and lead concentrations exceeded levels at which yield reduction or growth inhibition have been reported in the literature, and exceeded concentrations reported as "phytotoxically excessive" (Kabata-Pendias and Pendias, 1984). Zinc concentrations at three locations at the site (16SS01, 14SUB01, 14SS01) exceeded levels at which yield reductions have been reported in the literature, and exceeded concentrations reported as "phytotoxically excessive" (Kabata-Pendias and Pendias, 1984).

These results show that there are some locations at the site at which phytotoxic effects may occur.

### 5.4 Risk Characterization for Soil Invertebrates

Potential effects to soil invertebrates inhabiting the site were assessed by comparing soil concentrations to available soil invertebrate toxicity data (Table 4-5). Toxicity data were available for 6 of the organics and the majority of the inorganic chemicals of potential concern. Exceedances of toxicity data were observed for chlordane, DDE, copper, and zinc. The maximum detected concentration of chlordane (sampling location 13SS02) exceeded a LOEC (lowest observed effect concentration) of 6.25 mg/kg for sperm count depression in earthworms. At 2 out of the 34 sampling locations (13SS02 and 17SB03), DDE concentrations exceeded a toxicity value of 1.5 mg/kg for significant epidermal changes such as blisters and erythema of the clitellum in earthworms. At 37% of the soil sampling locations (13/35), copper concentrations exceeded the $EC_{50}$ (50% effect concentration) of 53 mg/kg for cocoon production in earthworms. In addition, the maximum detected value of copper at the site in the vicinity of Building 295 (14SUB01) exceeded earthworm $LC_{50}$s (lethal concentration for 50% of the organisms). Zinc concentrations at 3 out of 35 locations at the site (16SS01, 14SUB01, 14SS01) exceeded an $EC_{50}$ value of 53 mg/kg for cocoon production in earthworms. The maximum concentration of zinc in the vicinity of the propellant storage area (sample location 16SS01) exceeded $LC_{50}$s reported for earthworms.

## 6.0 UNCERTAINTY ANALYSIS

An ecological risk assessment is subject to a wide variety of uncertainties. Virtually every step in the risk assessment process involves numerous assumptions which contribute to the total uncertainty in the final evaluation of risk.

In the exposure assessment, numerous assumptions were made in order to estimate daily doses for selected indicator species (i.e., Northern short-tailed shrew, white-footed mouse, American robin, and song sparrow). Since limited site-specific information was available, assumptions were made regarding chemical concentrations in food items (*e.g.*, earthworms, plant seeds) and ingestion rates. In general, an effort was made to use assumptions that were conservative, yet realistic.

The interpretation and application of toxicological data in the toxicity assessment are probably the greatest sources of uncertainty in an ecological risk assessment. Frequently, data from literature sources are not specific to the indicator species selected, and therefore, extrapolation of the data to the species of concern is necessary. When extrapolating ecological data, every effort was made to use data from the most closely related species to the indicator organism. Even so, species sensitivities may vary even among closely related species. Variations in species sensitivity may be due to differences in some of the following factors: tolerance thresholds, toxic symptoms exhibited, time period until toxic effects are observed, and metabolism of ingested chemical.

In calculating RTVs, safety factors are applied to toxicity data to account for differences in species and difference in toxicological endpoints (*e.g.*, $LD_{50}$, NOAEL, LOAEL). The safety factors which were applied were either recommended by the EPA, developed from literature reviews of toxicological data, or based on best professional judgment. There are uncertainties associated with applying safety factors. For example, in deriving RTVs based on data from a different species, a safety factor is used to protect for the possibility that the indicator species may be more sensitive to a chemical exposure than the test species, even

though the opposite may be true. Thus, the potential exists for developing an overly protective RTV.

An additional uncertainty in developing RTVs is estimating a mg/kg-day intake from a dose reported as ppm in the diet. Where information from the study was not available to make this conversion, average ingestion rates and body weights were used to estimate an RTV.

An uncertainty which may result in an underestimate of risk in the risk characterization is the absence of toxicity data (*e.g.*, avian toxicity data for PAHs). In the absence of such information, the potential risk from exposure to chemicals of potential concern cannot be quantitatively evaluated.

Another uncertainty that may result in an underestimate of risk is associated with the use of RTVs developed from limited toxicological data. Since few data exist for dietary exposure to some chemicals (*e.g.*, mammalian exposure to DDD and PAHs) it is uncertain whether or not the existing studies have identified the most sensitive endpoints. In addition, for some chemical only acute data were available (*e.g.*, avian exposure to chlordane, DDD, and Aroclor 1260), and therefore does not account for potential chronic effects from exposure to these chemicals. Thus, basing the RTV on one of these studies may not protect against adverse effects to the most sensitive toxicological endpoint.

Risks were calculated on a chemical-by-chemical basis. Calculating risk in this manner does not account for additivity, synergism, or antagonism of chemicals to which receptors are exposed. This procedure may result in an overestimation or underestimation of potential risk.

The following text provides a brief discussion of the primary uncertainties associated with the risk evaluation for the indicator species/communities. The discussion focuses on those chemicals and/or exposure routes that are responsible for the majority of the risk.

## 6.1 Northern Short-tailed Shrew

Exposure Assessment:

- It was assumed that the Northern short-tailed shrew is present at the site. This assumption is based on the similarity between habitat conditions at the site and descriptions of short-tailed shrew habitat in the scientific literature. Moreover, the short-tailed shrew is known to occur locally (DeGraaf and Rudis, 1986).

- The diet of the shrew in a given location is based on food availability and can consist of the following organisms: earthworms, spiders, millipedes, centipedes, sow bugs, small vertebrates, plants, and insect larvae and pupae (DeGraaf and Rudis, 1986). Since data are not available to estimate chemical concentrations in other probable food sources, exposure dose estimates were based on exclusive consumption of earthworms. Since earthworms inhabit and ingest soil, they may be more efficient accumulators of soil contaminants than some of these other organisms. Thus, the assumption of an exclusive earthworm diet may overestimate the hazard to the shrew.

- There is some uncertainty associated with the food ingestion rate used for the short-tailed shrew. A number of references (EPA, 1993; Churchfield, 1990; Opresko et al., 1994) report that short-tailed shrews ingest approximately 60% of their body weight per day, or 9 g/day (as wet weight). This value (as converted to dry weight) was used in this assessment. This ingestion rate was measured in the laboratory under conditions of thermoneutrality (Merritt, 1995). Baker (1983), however, reported that physiological data measured for the short-tailed shrew (*i.e.*, heartbeat of 740-760/minute, respiration rate of 164 breaths/min., body temperature of 38°C, metabolic rate of 3.18 $cm^3$ $O_2$/gm/hr) "point to the need for the short-tailed shrew to eat between half and three times its body weight per day". The ingestion rates that Baker presents are not observed values, but were estimated based on physiological data (Merritt, 1995). For comparison purposes, the hazard indices for the shrew were recalculated using the midpoint (175% of the body weight) of the range of ingestion rates presented by Baker (1983). A food ingestion rate of 175% of the body weight was converted to 26 g/day wet weight intake, assuming a body weight of 15 g. Assuming a moisture content of 75% in earthworms, a dry weight intake of 6.6 g/day was estimated. The soil ingestion rate was estimated to be 0.68 g/day based on 10.4% of the dry weight intake. The resulting hazard indices were as follows:

| Mean | Upper 95% Confidence Limit |
|---|---|
| - Chlordane (29) | - Chlordane (97) |
| - DDE (2.1) | - DDE (9.6) |
| - DDT (19) | - DDT (110) |
| - Dieldrin (2.3) | - Dieldrin (6.4) |
| - Endrin (8.8) | - Endrin (16) |
| - PCB (2.2) | - PCB (3.4) |
| - Arsenic (24) | - Arsenic (30) |
| - Cadmium (4.3) | - Cadmium (5.1) |
| - Chromium (51) | - Chromium (57) |
| - Lead (64) | - Lead (88) |
| - Manganese (6.5) | - Manganese (7.4) |
| - Nickel (860) | - Nickel (1000) |
| - Zinc (30) | - Zinc (35) |

These hazard indices are approximately 2.5 times greater than those presented in the body of the report, and most likely represent an upperbound estimate of risk for the shrew.

- There are a number of difficulties associated with applying literature-based earthworm BAFs to a given site. Environmental variables, such as soil characteristics, obscure the underlying relationship between concentrations in soils and in earthworms. Earthworms selectively feed on plant debris and soil organic matter, and consequently, soil concentrations may not represent true exposure concentrations. Also, different earthworm species bioaccumulate chemicals at different rates (Beyer, 1990). Thus, there is uncertainty associated with applying literature-based earthworm BAFs to the AMTL site.

- It is not known how available metals and other inorganics in earthworm tissue are to predators. The presence of high levels of metals in earthworm tissue is not adequate proof that they will be absorbed by the predator (Lee, 1985). Thus, if metals are not in a bioavailable form in earthworms, they may not pose a hazard to wildlife at the site.

- The chemical form of a metal is an important factor in determining the level of exposure at which toxicity appears (Lee, 1985). The metal concentrations in soils at the site were analyzed as total metals, and thus the actual form of the metal in soils and in earthworms is not known. As a general rule, the more bioavailable forms of chemicals are used in toxicity tests. Thus, it is possible that the form of a metal in the earthworms at the site is in a less bioavailable form than that used in the study on which the RTV is based. In such a case, the estimated hazard from exposure to such a chemical would be overestimated. For nickel, it is important to note that the shrew RTV is based on a drinking water study in which a soluble salt of nickel was used. Nickel is most likely more available for uptake from water, as a soluble salt,

than from soils or earthworms. This indicates that the hazard to nickel may have been overestimated at the site.

Effects Characterization/Risk Characterization:

- No toxicity data were available specifically for the shrew; therefore, data from other small mammal species were used.

- The RTV for nickel was based on a chronic effect dose for rats, in which an increase in deaths and runts were observed in the young. A safety factor of 5 was used to extrapolate from a chronic effect dose to a safe chronic dose. It is not known whether this safety factor over- or under-estimates risk. An additional safety factor of 5 was used to extrapolate between species. If the shrew is as or less sensitive to nickel exposure than the rat, the RTV may result in an overestimation of risk. Also, as mentioned previously, the nickel was administered in drinking water as a soluble salt in the RTV study (Schroeder and Mitchener, 1971), which is a very bioavailable form of nickel. Although the extent of nickel bioavailability from earthworms or soil is not known, it is most likely not as bioavailable as the form of nickel in the RTV study. Thus, the use of this study to develop the nickel RTV may overestimate the risk to small mammals.

- The RTV for DDT was based on a chronic NOAEL for pup growth in rats. The NOAEL was 1 mg/kg-day, with an associated LOAEL of 10 mg/kg-day (Clement and Okey, 1974). Since the true no effect level lies somewhere between 1 and 10 mg/kg-day, the RTV most likely overestimates risk. In addition, an inter-species safety factor of 5, which was applied to the RTV, may result in an overestimate of risk if the shrew is as or less sensitive to chlordane exposure compared to the rat.

- The RTV for lead was based on a chronic NOAEL for depressed immunity in rats. A safety factor of 5 was used to extrapolate between species. If the shrew is as or less sensitive to nickel exposure than the rat, the RTV may result in an overestimation of risk. In the RTV study, the lead was administered in drinking water as lead acetate (Luster et al., 1978), which is a bioavailable form of lead. Although the extent of lead bioavailability from earthworms or soil is not known, it is most likely not as bioavailable as the form of lead in the RTV study. Thus, the use of this study to develop the lead RTV may overestimate the risk to small mammals.

- The RTV for chlordane was based on a chronic NOAEL for liver lesions in mice. This NOAEL was based on 5 ppm of chlordane administered in the diet. Although liver lesions were observed at this dose, these effects were not statistically significant. Significant effects were observed at the highest dose (12.5 ppm). The authors stated, however, that although changes in the liver appeared earlier and at a greater frequency in mice fed 12.5 ppm of chlordane, these changes only appeared at the end of what would be the

normal lifespan for these mice (2 years). Thus, there is some question as to the ecological significance of this endpoint. It is possible that liver lesions would not significantly affect small mammal health and population levels in the field. Thus, there is uncertainty in the ecological significance of the chlordane RTV.

- Since metals occur naturally in soils, one needs to consider whether metals detected at the site are due to contamination or based on natural background levels. Table A-8 (Appendix A) presents means and ranges of background metal concentrations measured in U.S. soils. The ranges that are presented often span many orders of magnitude, and are most likely a reflection of the diverse environments that were sampled. Thus, these background values can only be used as general guidance in determining whether a metal is at background levels at the site. Other factors need to be considered, such as the range and distribution of metal concentrations at the site. The metals at the site which exceeded background ranges at one or more locations were cadmium, copper, lead, and zinc. Cadmium exceeded background ranges at sampling locations 16SS01, 14SUB01, and 14SUB02. Copper exceeded background ranges at sampling location 14SUB01. Lead exceeded background levels at a number of locations. Zinc exceeded background ranges as reported in Kabata-Pendias and Pendias (1984) at sampling locations 16SS01, 14SUB01, 14SS01. For other metals such as arsenic, chromium, manganese, and nickel, it becomes more difficult to determine what is or is not due to background. Although these metals fall within the natural background ranges, there are a few site values which appear to be higher than the majority of values measured at the site. For example, the maximum arsenic concentration of 52 mg/kg (sampling location 14SUB01) appears to be slightly higher than other arsenic values. For chromium there are a few values (sampling locations 16SS01 and 14SS03) that appear to be slightly elevated. For manganese there are a few values (sampling locations 14SUB01, 13SUB02, and 16SS01) that appear to be slightly elevated. For nickel, it appears that there may be some elevated concentrations (possibly locations 14SS03 and 12SUB01). Approximately 85% of the nickel concentrations at the site fell within a range of 10 to 45 ppm. There were three concentrations that fell within 50-60 ppm, one value at 73 ppm (12SUB01), and the maximum concentration of nickel at 99 ppm (14SS03). Although some values appear to be slightly elevated it is possible that these values are upper-end background concentrations. Thus, there is uncertainty associated with whether risks determined for some metals (particularly arsenic, chromium, manganese, and nickel) are due to background or to site-related activities.

## 6.2 <u>White-Footed Mouse</u>

Exposure Assessment:

- It was assumed that the white-footed mouse is present at the site. This assumption is based on the similarity between habitat conditions at the site and descriptions of white-footed mouse habitat in the scientific literature. Moreover the white-footed mouse is known to occur locally (DeGraaf and Rudis, 1986).

- Chemical concentrations in plant seeds are dependent on such factors as plant species considered, site-specific conditions (*i.e.*, soil type, soil pH, soil organic content), chemical species, etc. Plant uptake factors (PUFs) for organics were calculated based on a regression equation which incorporates chemical-specific log Kows. Uncertainty exists in using predicted values such as these. The PUFs used for inorganics were based on data from Baes et al. (1984), who derived uptake factors based on a literature review, and comparisons of observed and predicted elemental concentrations in plants (Baes et al. 1984). Inorganics can exist in soils as free ionic forms, inorganic ion pairs, inorganic complexes, organic complexes, etc., each with its own propensity toward biouptake, trophic transfer, and subsequent toxicity. Because the form of the element in the environment is difficult to predict or is seldom measured, prediction of the mobilization and uptake of metals is highly uncertain. Therefore, the concentrations of chemicals in plant seeds, and subsequent risk from ingestion of seeds, is a major uncertainty.

- The chemical form of a metal is an important factor in determining the level of exposure at which toxicity appears (Lee, 1985). The metal concentrations in soils at the site were analyzed as total metals, and thus the actual form of the metal in soils and in plants is not known. As a general rule, the more bioavailable forms of chemicals are used in toxicity tests. Thus, it is possible that the form of a metal in plants at the site is in a less bioavailable form than that used in the study on which the RTV is based. In such a case, the estimated hazard from exposure to such a chemical would have been overestimated. As discussed for the shrew, the nickel RTV is based on a drinking water study in which a soluble salt of nickel was used. Nickel is most likely more available from water, as a soluble salt, than from soils or plants. This indicates that the hazard to nickel may have been overestimated at the site.

Effects Characterization/Risk Characterization:

- White-footed mouse toxicity data were not available for any chemicals of concern; therefore, interspecies extrapolation was required for all of the chemicals of concern. If the white-footed mouse is as or less sensitive to a chemical as compared to the test species, then the risk to the mouse will be overestimated.

- There is considerable uncertainty associated with the RTVs derived for nickel and chlordane, as discussed under the uncertainty analysis for the shrew.

- As discussed for the shrew, there is uncertainty associated with whether risks determined for some metals are due to background or to site-related activities.

### 6.3 American Robin

Exposure Assessment:

- The diet of the robin in a given location is based on food availability and can consist of the following organisms: earthworms, grasshoppers, beetles, cicadas, ants, termites, cutworms, caterpillars, butterflies, and berries (Terres, 1991). Since data are not available to estimate chemical concentrations in other probable food sources, exposure dose estimates were based on exclusive consumption of earthworms. Since earthworms inhabit and ingest soil, they may be more efficient accumulators of soil contaminants than some of these other organisms. Thus, the assumption of an exclusive earthworm diet may overestimate the hazard to the robin.

- As discussed under the uncertainty analysis for the shrew, there are many uncertainties associated with using literature-based bioaccumulation factors for earthworms.

- As discussed under the uncertainty analysis for the shrew, it is not known how available the metals and other inorganics in earthworm tissue are to predators.

Effects Characterization/Risk Characterization:

- No toxicity data were available for the robin; therefore, data from other bird species were used.

- Toxicity data for avian species were not available for PAHs; therefore, the potential risk from exposure to these chemicals could not be estimated for the robin.

- The RTV for DDT was based on a chronic NOAEL for eggshell thinning in mallards. This NOAEL was based on 2 ppm of DDT administered in the diet. The next highest dose that was tested was 20 ppm (LOAEL). Since the true no effect level lies somewhere between 2 and 20 ppm, the RTV most likely overestimates risk. In addition, an inter-species safety factor of 5, which was applied to the RTV, may result in an overestimate of risk if the robin is

as or less sensitive to DDT exposure compared with the mallard. Thus, there is some uncertainty associated with the avian RTV for DDT.

- The RTV for DDE was based on a chronic effect dose for eggshell thinning, eggshell cracking, and duckling survival in black ducks. Since there is no associated NOAEL reported in this study, it is uncertain whether this RTV results in an over- or under-estimation of risk.

- The RTVs for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, and extrapolated to acute no effect levels. The potential for chronic effects to occur based on exposure to these chemicals could not be evaluated due to a lack of sufficient chronic toxicity data.

## 6.4 Song Sparrow

Exposure Assessment:

- The diet of the song sparrow in a given location is based on food availability and can consist of the following organisms: seeds of grasses and weeds, wild fruits, beetles, grasshoppers, cutworms, army worms, ants, wasps, flies, termites, bugs, leafhoppers, etc. (Terres, 1991). Since data are not available to estimate chemical concentrations in other probable food sources, exposure dose estimates were based on exclusive consumption of plant seeds. It is uncertain whether this assumption may over- or under-estimate potential risk.

- As discussed under the uncertainty analysis for the white-footed mouse, there are many uncertainties associated with using literature-based plant uptake factors.

Effects Characterization/Risk Characterization:

- No toxicity data were available for the song sparrow; therefore, data from other bird species were used.

- Toxicity data for avian species were not available for PAHs; therefore, the potential risk from exposure to these chemicals could not be estimated for the song sparrow.

- The RTVs for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, and extrapolated to acute no effect levels. The potential for chronic effects to occur based on exposure to these chemicals could not be evaluated due to a lack of sufficient chronic toxicity data.

## 6.5 Terrestrial Vegetation

- Since phytotoxic effects are plant species-specific and directly related to ambient conditions (*i.e.*, soil type, soil pH, moisture content etc.), comparison of literature-based phytotoxicity data to soil concentrations at the AMTL site may not accurately illustrate potential hazards to on-site plants.

- Phytotoxicity of metals is dependent on the chemical form of the metal that was used in the study. Many of the secondary sources from which the phytotoxicity data were taken do not provide information on the form of the metal used in the studies.

- Some secondary references from which phytotoxicity data were taken do not provide information on the plant species used in the studies, or endpoints that were measured. For example, Kabata-Pendias and Pendias (1984) provide "phytotoxically excessive" levels, but do not provide any details on plant species or toxicological endpoints. Thus, there is uncertainty as to what these values represent.

- As discussed for the shrew, there is uncertainty associated with whether some metal concentrations at the site are due to background or to site-related activities.

## 6.6 Soil Invertebrates

- Since toxic effects to soil invertebrates are species-specific and directly related to ambient conditions (*i.e.*, soil type, soil pH, moisture content etc.), comparison of literature-based invertebrate toxicity data to soil concentrations at the AMTL site may not accurately illustrate potential hazards to these organisms.

- The potential effects on soil invertebrates from exposure to DDT was based on data reported in units of kg/hectare. These data were converted to a mg/kg basis, by assuming a soil density of 1.5 g/cm$^3$, and a mixing depth of 1 cm (EPA, 1990b). There are uncertainties associated with this conversion.

- The chemical form of a metal is an important factor in determining the level of exposure at which toxicity appears (Lee, 1985). The metal concentrations in soils at the site were analyzed as total metals, and thus the actual form of the metal in soils is not known. As a general rule, the more bioavailable forms of chemicals are used in toxicity tests. Thus, it is possible that the form of a metal in soils at the site is in a less bioavailable form than that used in toxicity studies.

- As discussed for the shrew, there is uncertainty associated with whether some metal concentrations at the site are due to background or to site-related activities.

## 7.0 CONCLUSIONS

The results of the terrestrial ecological risk assessment show the potential for adverse effects to occur to insectivorous small mammals, herbivorous small mammals, omnivorous passerines (*i.e.*, perching birds), plants, and soil invertebrates at the AMTL site.

For mammals, the highest hazard index was based on potential exposure to nickel. The nickel hazard indices observed for insectivorous mammals (*i.e.*, 360 to 420) were higher than those observed for herbivorous mammals (*i.e.*, 16 to 19). The majority of the hazard index for nickel, as well as most of the other contaminants was due to potential bioconcentration and exposure through earthworm or seed ingestion. The concentrations of nickel at the site fell within the means and ranges of background nickel concentrations measured in U.S. soils (Table A-8). On examining the distribution of nickel concentrations at the site, approximately 85% of the concentrations fell within concentrations of 10 to 45 ppm. There were three concentrations that fell within 50 to 60 ppm, one value at 73 ppm, and the maximum concentration of nickel at 99 ppm. It is uncertain whether the higher nickel concentrations are based on site-related activities or are upper-end background concentrations.

The basis of the RTV used for nickel also needs to be considered. The nickel RTV was based on chronic effects in rats, in which an increase in deaths and runts were observed in the young. An increase in deaths and runts in the young would potentially affect the population levels of small mammals at the site. However, in the RTV study, the nickel was administered in drinking water as a soluble salt, which is a very bioavailable form of nickel, and thus may tend to overestimate risk based on nickel exposure at the site.

In addition to nickel, there were a number of other chemicals that exceeded a hazard index of one for small mammals, particularly for the insectivorous small mammals (*e.g.*, chlordane,

DDT, lead, chromium, zinc). These hazard indices were generally much lower than those observed for nickel, and ranged from 1.5 to 46 for the insectivorous mammals, and 1.2 to 8.3 for herbivorous mammals.

The highest hazard indices observed for omnivorous passerines were based on exposure to DDT (48 to 280) and DDE (40 to 180). The majority of the hazard index for these chemicals, as well as for others, was due to earthworm ingestion. The RTV for DDT was based on a dietary study in which eggshell thinning was observed in mallards, and the RTV for DDE was based on eggshell thinning, eggshell cracking, and duckling survival in black ducks. Eggshell thinning and decrease in young survival would potentially affect bird population levels. Thus, the results show the potential for adverse reproductive effects in omnivorous passerines feeding at the site. Other chemicals which exceeded a hazard index of one included endrin (8.7 to 16), lead (5.4 to 7.4), zinc (5.6 to 6.4), nickel (3.3 to 3.9) and chlordane (2.8).

A comparison of soil concentrations at the site with phytotoxicity data show the potential for phytotoxic effects to occur at some locations on the site. Exceedances of phytotoxicity data occurred for arsenic, cadmium, copper, lead, and zinc. These metals occurred at concentrations on the site which have been shown to cause yield reductions, growth retardation, leaf discoloration, and reduced germination.

Potential effects to soil invertebrates may also occur at some locations at the site. Exceedances of toxicity data were observed for chlordane, DDE, copper, and zinc. The maximum detected concentrations of copper and zinc at the site, exceed $LC_{50}$s for earthworms, and a number of other locations exceeded an $EC_{50}$ value for cocoon production in earthworms. The organics exceeded concentrations at which sperm count depression and epidermal changes have been observed in earthworms.

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# APPENDIX A

# SELECTION OF THE CHEMICALS OF POTENTIAL CONCERN

Table A-1

Selection of Chemicals of Potential Concern in Soils [a]

| Chemicals | Range of Hits (mg/kg) | | | Frequency of Detection | Range of Quantitation Limits | | | Reason for Exclusion as a COPC |
|---|---|---|---|---|---|---|---|---|
| *Organics* | | | | | | | | |
| Acenaphthene | 0.084 | – | 0.479 | 7 / 28 | 0.041 | – | 4.100 | See PAHs – low MW |
| Acenaphthylene | 0.163 | – | 4.190 | 9 / 28 | 0.033 | – | 4.600 | See PAHs – low MW |
| Acetone | 0.012 | – | 0.051 | 5 / 23 | 0.011 | – | 3.300 | Below Screening Levels |
| Aldrin | 0.006 | – | 0.008 | 2 / 34 | 0.001 | – | 1.300 | Below Screening Levels; low frequency of detection |
| **Alpha–Chlordane** | 0.005 | – | 0.155 | 9 / 11 | 0.002 | – | 0.002 | |
| Alpha–Endosulfan | 0.002 | – | 0.014 | 4 / 33 | 0.001 | – | 1.000 | Below Screening Levels; low frequency of detection |
| Alpha–Hexachlorocyclohexane | | – | | 0 / 34 | 0.003 | – | 1.300 | Not detected |
| Anthracene | 1.590 | – | 14.500 | 4 / 28 | 0.540 | – | 5.400 | See PAHs – low MW |
| Benzene | 0.258 | – | 0.258 | 1 / 23 | 0.003 | – | 0.100 | Below Screening Levels; low frequency of detection |
| Benzo (a) anthracene | 0.214 | – | 31.500 | 21 / 28 | 0.041 | – | 3.000 | See PAHs – high MW |
| Benzo (a) pyrene | 0.827 | – | 36.600 | 6 / 28 | 0.380 | – | 3.800 | See PAHs – high MW |
| Benzo (b) fluoranthene | 0.713 | – | 15.400 | 12 / 28 | 0.310 | – | 3.600 | See PAHs – high MW |
| Benzo (g,h,i) perylene | 0.378 | – | 13.600 | 13 / 28 | 0.180 | – | 2.400 | See PAHs – high MW |
| Benzo (k) fluoranthene | 0.406 | – | 23.600 | 15 / 28 | 0.130 | – | 8.000 | See PAHs – high MW |
| Benzoic acid | | – | | 0 / 28 | 1.700 | – | 20.000 | Not Detected |
| Benzyl alcohol | 1.290 | – | 1.290 | 1 / 28 | 0.032 | – | 3.000 | Below Screening Levels; low frequency of detection |
| Beta–Endosulfan | 0.001 | – | 0.013 | 6 / 33 | 0.001 | – | 2.400 | Below Screening Levels |
| Beta–Hexachlorocyclohexane | | – | | 0 / 33 | 0.008 | – | 3.600 | Not Detected |
| Bis (2–chloroethyl) ether | | – | | 0 / 28 | 0.330 | – | 3.300 | Not Detected |
| Bis (2–chloroethyoxy) methane | | – | | 0 / 28 | 0.190 | – | 3.000 | Not Detected |
| Bis (2–chloroisopropyl) ether | | – | | 0 / 28 | 0.300 | – | 3.000 | Not Detected |
| Bis (2–ethylhexyl) phthalate | | – | | 0 / 28 | 0.390 | – | 3.900 | Not Detected |
| Bromodichloromethane | | – | | 0 / 24 | 0.003 | – | 0.200 | Not Detected |
| Bromofluorobenzene, 4– | | – | | 0 / 13 | 0.600 | – | 0.600 | Not Detected |
| Bromoform | | – | | 0 / 24 | 0.018 | – | 0.200 | Not Detected |
| Bromomethane | | – | | 0 / 24 | 0.010 | – | 0.260 | Not Detected |
| Bromophenylphenyl ether, 4– | | – | | 0 / 29 | 0.041 | – | 3.000 | Not Detected |
| Butanone, 2– | 0.018 | – | 0.018 | 1 / 24 | 0.010 | – | 4.300 | Below Screening Levels; low frequency of detection |
| Butylbenzyl phthalate | 0.476 | – | 1.100 | 3 / 29 | 0.300 | – | 3.000 | Below Screening Levels; low frequency of detection |
| Carbon disulfide | | – | | 0 / 23 | 0.005 | – | 0.600 | Not Detected |
| Carbon tetrachloride | | – | | 0 / 23 | 0.005 | – | 0.310 | Not Detected |
| **Chlordane** | 0.324 | – | 9.360 | 16 / 33 | 0.068 | – | 30.000 | |
| Chloroaniline, 4– | | – | | 0 / 28 | 0.300 | – | 3.000 | Not Detected |
| Chlorobenzene | | – | | 0 / 23 | 0.003 | – | 0.100 | Not Detected |
| Chloroethane | | – | | 0 / 23 | 0.022 | – | 0.640 | Not Detected |
| Chloroethylvinyl ether, 2– | | – | | 0 / 23 | 0.048 | – | 0.500 | Not Detected |
| Chloroform | | – | | 0 / 23 | 0.002 | – | 0.240 | Not Detected |
| Chloromethane | | – | | 0 / 23 | 0.010 | – | 0.960 | Not Detected |
| Chloronaphthalene, 2– | | – | | 0 / 28 | 0.240 | – | 3.200 | Not Detected |
| Chlorophenol, 2– | | – | | 0 / 28 | 0.055 | – | 3.000 | Not Detected |
| Chlorophenylmethyl sulfide, p– | | – | | 0 / 28 | 0.097 | – | 3.700 | Not Detected |
| Chlorophenylmethyl sulfone, p– | | – | | 0 / 28 | 0.066 | – | 6.900 | Not Detected |
| Chlorophenylmethyl sulfoxide, | | – | | 0 / 28 | 0.270 | – | 2.700 | Not Detected |
| Chlorophenylphenyl ether, 4– | | – | | 0 / 28 | 0.170 | – | 3.000 | Not Detected |
| Chrysene | 0.076 | – | 33.900 | 16 / 28 | 0.032 | – | 4.500 | See PAHs – high MW |
| **DDD** | 0.004 | – | 3.480 | 16 / 34 | 0.003 | – | 0.064 | |
| **DDE** | 0.004 | – | 6.330 | 26 / 34 | 0.003 | – | 0.068 | |
| **DDT** | 0.010 | – | 5.200 | 17 / 33 | 0.004 | – | 4.100 | |
| Delta–Hexachlorocyclohexane | 0.020 | – | 0.034 | 3 / 34 | 0.005 | – | 0.210 | Low frequency of detection; 1 hit only slightly exceeds SL |
| Di–N–butyl phthalate | | – | | 0 / 28 | 0.300 | – | 3.000 | Not Detected |
| Di–N–octyl phthalate | | – | | 0 / 28 | 0.230 | – | 5.900 | Not Detected |
| Dibenz (a,h) anthracene | 0.468 | – | 3.340 | 3 / 28 | 0.200 | – | 2.000 | See PAHs – high MW |
| Dibenzofuran | | – | | 0 / 28 | 0.038 | – | 3.000 | Not Detected |
| Dibromochloromethane | | – | | 0 / 23 | 0.014 | – | 0.250 | Not Detected |
| Dibromochloropropane | | – | | 0 / 18 | 0.071 | – | 0.071 | Not Detected |
| Dichlorobenzene, 1,2– | | – | | 0 / 28 | 0.001 | – | 0.042 | Not Detected |
| Dichlorobenzene, 1,3– | | – | | 0 / 28 | 0.002 | – | 0.042 | Not Detected |
| Dichlorobenzene, 1,4– | | – | | 0 / 28 | 0.001 | – | 0.034 | Not Detected |
| Dichlorobenzidine, 3,3'– | | – | | 0 / 28 | 0.200 | – | 2.000 | Not Detected |
| Dichloroethane, 1,1– | | – | | 0 / 23 | 0.002 | – | 0.490 | Not Detected |
| Dichloroethane, 1,2– | | – | | 0 / 23 | 0.003 | – | 0.320 | Not Detected |
| Dichloroethenes, 1,2– (cis and | | – | | 0 / 23 | 0.002 | – | 0.320 | Not Detected |
| Dichloroethylene, 1,1– | | – | | 0 / 23 | 0.017 | – | 0.270 | Not Detected |
| Dichlorophenol, 2,4– | | – | | 0 / 28 | 0.065 | – | 3.000 | Not Detected |
| Dichloropropane, 1,2– | | – | | 0 / 23 | 0.002 | – | 0.530 | Not Detected |
| Dichloropropane, 1,3– | | – | | 0 / 23 | 0.001 | – | 0.200 | Not Detected |
| Dichloropropene, 1,3– trans | | – | | 0 / 23 | 0.005 | – | 0.600 | Not Detected |
| Dichloropropylene, 1,3– cis | | – | | 0 / 23 | 0.005 | – | 0.600 | Not Detected |
| Dicyclopentadiene | | – | | 0 / 18 | 0.570 | – | 0.570 | Not Detected |
| **Dieldrin** | 0.007 | – | 0.312 | 14 / 34 | 0.002 | – | 0.079 | |
| Diethyl phthalate | | – | | 0 / 28 | 0.240 | – | 3.000 | Not Detected |
| Dimethyl phthalate | | – | | 0 / 28 | 0.063 | – | 3.000 | Not Detected |
| Dimethylbenzene, 1,2– / o–Xyle | | – | | 0 / 10 | 0.005 | – | 0.006 | Not Detected |

## Table A-1 (cont'd.)

### Selection of Chemicals of Potential Concern in Soils [a]

| Chemicals | Range of Hits (mg/kg) | | | Frequency of Detection | Range of Quantitation Limits | | Reason for Exclusion as a COPC |
|---|---|---|---|---|---|---|---|
| Dimethylbenzene, 1,3– / m–Xyle | | – | | 0 / 23 | 0.005 – | 0.230 | Not Detected |
| Dimethylphenol, 2,4– | | – | | 0 / 28 | 0.300 – | 3.000 | Not Detected |
| Dinitroaniline, 2,6– | | – | | 0 / 18 | 0.570 – | 0.570 | Not Detected |
| Dinitroaniline, 3,5– | | – | | 0 / 18 | 1.600 – | 1.600 | Not Detected |
| Dinitrobenzene, 1,3– | | – | | 0 / 4 | 0.504 – | 0.504 | Not Detected |
| Dinitrophenol, 2,4– | | – | | 0 / 28 | 1.700 – | 20.000 | Not Detected |
| Dinitrotoluene, 2,4– | | – | | 0 / 32 | 0.390 – | 3.900 | Not Detected |
| Dinitrotoluene, 2,6– | | – | | 0 / 32 | 0.320 – | 5.300 | Not Detected |
| Diphenylhydrazine, 1,2– | | – | | 0 / 18 | 0.520 – | 0.520 | Not Detected |
| Dithiane | | – | | 0 / 28 | 0.065 – | 2.400 | Not Detected |
| Endosulfan sulfate | | – | | 0 / 33 | 0.001 – | 2.000 | Not Detected |
| **Endrin** | 0.013 | – | 0.500 | 11 / 34 | 0.007 – | 1.300 | |
| Endrin aldehyde | | – | | 0 / 18 | 1.800 – | 1.800 | Not Detected |
| Endrin ketone | | – | | 0 / 33 | 0.001 – | 2.000 | Not Detected |
| Ethylbenzene | | – | | 0 / 23 | 0.003 – | 0.190 | Not Detected |
| Fluoranthene | 0.132 | – | 54.100 | 21 / 28 | 0.520 – | 5.200 | See PAHs – high MW |
| Fluorene | 0.159 | – | 1.050 | 7 / 28 | 0.065 – | 3.000 | See PAHs – low MW |
| **Gamma–Chlordane** | 0.014 | – | 0.173 | 6 / 11 | 0.004 – | 0.004 | |
| Gamma–Hexachlorocyclohexane | | – | | 0 / 34 | 0.001 – | 0.100 | Not Detected |
| HMX | | – | | 0 / 4 | 2.000 – | 2.000 | Not Detected |
| Heptachlor | 0.013 | – | 0.013 | 1 / 34 | 0.001 – | 0.240 | Below Screening Levels; low frequency of detection |
| Heptachlor epoxide | 0.002 | – | 0.119 | 13 / 34 | 0.001 – | 0.480 | Only 1 value slightly above lowest SL |
| Hexachlorobenzene | | – | | 0 / 28 | 0.080 – | 2.600 | Not Detected |
| Hexachlorobutadiene | | – | | 0 / 28 | 0.420 – | 4.200 | Not Detected |
| Hexachlorocyclopentadiene | | – | | 0 / 28 | 0.300 – | 3.000 | Not Detected |
| Hexachloroethane | | – | | 0 / 28 | 0.400 – | 4.000 | Not Detected |
| Hexanone, 2– | | – | | 0 / 23 | 0.010 – | 1.000 | Not Detected |
| Indeno (1,2,3–cd) pyrene | 0.322 | – | 10.400 | 5 / 28 | 0.210 – | 2.400 | See PAHs – high MW |
| Isodrin | 0.031 | – | 0.343 | 6 / 34 | 0.003 – | 0.480 | Below Screening Levels |
| Isophorone | | – | | 0 / 28 | 0.300 – | 3.000 | Not Detected |
| Malathion | | – | | 0 / 28 | 0.180 – | 4.800 | Not Detected |
| Methoxychlor | 0.051 | – | 0.470 | 4 / 33 | 0.036 – | 10.000 | Only 1 value slightly above lowest SL |
| Methyl–4,6,dinitrophenol, 2– | | – | | 0 / 28 | 0.800 – | 20.000 | Not Detected |
| Methyl–4–chlorophenol, 3– | | – | | 0 / 28 | 0.300 – | 3.000 | Not Detected |
| Methylene chloride | | – | | 0 / 23 | 0.005 – | 4.400 | Not Detected |
| Methylisobutyl ketone | | – | | 0 / 23 | 0.010 – | 0.630 | Not Detected |
| Methylnaphthalene, 2– | 0.064 | – | 0.323 | 7 / 28 | 0.032 – | 3.000 | Below Screening Levels |
| Methylphenol, 2– | | – | | 0 / 28 | 0.098 – | 3.000 | Not Detected |
| Methylphenol, 4– | | – | | 0 / 28 | 0.240 – | 3.000 | Not Detected |
| Mirex | | – | | 0 / 18 | 0.140 – | 0.140 | Not Detected |
| N–Nitrosodi–N–propylamine | | – | | 0 / 18 | 1.100 – | 1.100 | Not Detected |
| N–Nitrosodiphenylamine | | – | | 0 / 28 | 0.300 – | 3.000 | Not Detected |
| N–Nitrosodiphenylamine | | – | | 0 / 18 | 0.290 – | 0.290 | Not Detected |
| Naphthalene | | – | | 0 / 28 | 0.420 – | 4.200 | Not Detected |
| Nitroaniline, 2– | | – | | 0 / 28 | 1.700 – | 20.000 | Not Detected |
| Nitroaniline, 3– | | – | | 0 / 28 | 1.700 – | 20.000 | Not Detected |
| Nitroaniline, 4– | | – | | 0 / 28 | 1.700 – | 20.000 | Not Detected |
| Nitrobenzene | | – | | 0 / 32 | 0.300 – | 3.000 | Not Detected |
| Nitrophenol, 2– | | – | | 0 / 28 | 0.300 – | 3.000 | Not Detected |
| Nitrophenol, 4– | | – | | 0 / 28 | 1.700 – | 20.000 | Not Detected |
| Nitrosodi–N–propylamine | | – | | 0 / 10 | 0.360 – | 3.600 | Not Detected |
| Nitrotoluene, 3– | | – | | 0 / 18 | 0.340 – | 0.340 | Not Detected |
| Oxathiane, 1,4– | | – | | 0 / 28 | 0.075 – | 2.500 | Not Detected |
| PAHs – low molecular weight [b,d] | 0.589 | – | 37.2 | 18 / 28 | 0.881 – | 21.2 | Below screening values |
| **PAHs – high molecular weight [c,d]** | 2.64 | – | 275 | 24 / 28 | 3.88 – | 38.8 | |
| Parathion | | – | | 0 / 28 | 0.460 – | 4.600 | Not Detected |
| PCB 1016 | | – | | 0 / 35 | 0.070 – | 1.000 | Not Detected |
| PCB 1221 | | – | | 0 / 24 | 0.100 – | 1.900 | Not Detected |
| PCB 1232 | | – | | 0 / 24 | 0.100 – | 1.900 | Not Detected |
| PCB 1242 | | – | | 0 / 24 | 0.100 – | 1.900 | Not Detected |
| PCB 1248 | | – | | 0 / 24 | 0.100 – | 1.900 | Not Detected |
| PCB 1254 | | – | | 0 / 24 | 0.048 – | 3.800 | Not Detected |
| **PCB 1260** | 0.084 | – | 4.870 | 6 / 35 | 0.048 – | 0.790 | |
| PCB 1262 | | – | | 0 / 18 | 6.300 – | 6.300 | Not Detected |
| Pentachlorophenol | | – | | 0 / 28 | 0.760 – | 20.000 | Not Detected |
| Phenanthrene | 0.164 | – | 16.800 | 18 / 28 | 0.032 – | 4.100 | See PAHs – low MW |
| Phenol | | – | | 0 / 28 | 0.052 – | 3.000 | Not Detected |
| Pyrene | 0.148 | – | 52.600 | 24 / 28 | 0.420 – | 4.200 | See PAHs – high MW |
| RDX | | – | | 0 / 4 | 1.280 – | 1.280 | Not Detected |
| Styrene | | – | | 0 / 23 | 0.005 – | 0.600 | Not Detected |
| Supona | | – | | 0 / 18 | 0.920 – | 0.920 | Not Detected |
| Tetrachloroethane, 1,1,2,2– | | – | | 0 / 23 | 0.002 – | 0.200 | Not Detected |
| Tetrachloroethene | 0.002 | – | 0.002 | 1 / 23 | 0.002 – | 0.160 | Below Screening Levels; low frequency of detection |
| TETRYL | | – | | 0 / 4 | 2.110 – | 2.110 | Not Detected |

## Table A-1 (cont'd.)

### Selection of Chemicals of Potential Concern in Soils [a]

| Chemicals | Range of Hits (mg/kg) | Frequency of Detection | Range of Quantitation Limits | Reason for Exclusion as a COPC |
|---|---|---|---|---|
| Toluene | 0.205 – 0.205 | 1 / 23 | 0.007 – 0.100 | Below Screening Levels; low frequency of detection |
| Toxaphene | – | 0 / 23 | 0.226 – 12.000 | Not Detected |
| Trichlorobenzene, 1,2,3– | – | 0 / 28 | 0.032 – 2.900 | Not Detected |
| Trichlorobenzene, 1,2,4– | – | 0 / 28 | 0.220 – 2.900 | Not Detected |
| Trichloroethane, 1,1,1– | – | 0 / 23 | 0.004 – 0.200 | Not Detected |
| Trichloroethane, 1,1,2– | – | 0 / 23 | 0.020 – 0.330 | Not Detected |
| Trichloroethylene | – | 0 / 23 | 0.004 – 0.230 | Not Detected |
| Trichlorophenol, 2,4,5– | – | 0 / 28 | 0.490 – 20.000 | Not Detected |
| Trichlorophenol, 2,4,6– | – | 0 / 28 | 0.061 – 20.000 | Not Detected |
| Trifluorochloromethane | – | 0 / 23 | 0.005 – 0.230 | Not Detected |
| Trinitrobenzene, 1,3,5– | – | 0 / 4 | 0.922 – 0.922 | Not Detected |
| Trinitrotoluene, 2,4,6– | – | 0 / 4 | 2.000 – 2.000 | Not Detected |
| Vapona | – | 0 / 18 | 0.068 – 0.068 | Not Detected |
| Vinyl acetate | – | 0 / 23 | 0.010 – 1.000 | Not Detected |
| Vinyl chloride | – | 0 / 23 | 0.010 – 1.800 | Not Detected |
| Xylenes | – | 0 / 13 | 0.780 – 0.780 | Not Detected |
| *Inorganics* | | | | |
| Aluminum | 6680.000 – 24833.333 | 35 / 35 | – | Within natural levels in lit. (although exceeds SLs) |
| Antimony | – | 0 / 35 | 4.680 – 19.600 | Not Detected |
| **Arsenic** | 3.200 – 52.000 | 35 / 35 | – | |
| Barium | 24.000 – 302.933 | 35 / 35 | – | Below Screening Levels |
| Beryllium | 0.192 – 5.024 | 23 / 35 | 0.427 – 0.684 | Below Screening Levels |
| Boron | 10.600 – 10.600 | 1 / 3 | 7.370 – 7.370 | Below Screening Levels |
| **Cadmium** | 0.771 – 3.530 | 4 / 35 | 0.447 – 1.200 | |
| Calcium | 829.000 – 9820.000 | 35 / 35 | – | Low toxicity; within natural levels in the lit. |
| **Chromium** | 12.900 – 71.200 | 35 / 35 | – | |
| Cobalt | 5.090 – 89.300 | 35 / 35 | 1.500 – 1.500 | Only one value marginally exceeds Screening Levels |
| **Copper** | 22.550 – 1550.000 | 35 / 35 | – | |
| Iron | 1730.000 – 130000.000 | 35 / 35 | – | Low toxicity; within natural levels in the lit. |
| **Lead** | 37.800 – 521.000 | 33 / 34 | 54.700 – 54.700 | |
| Magnesium | 1730.000 – 8340.000 | 35 / 35 | – | Low toxicity; within natural levels in the lit. |
| **Manganese** | 197.000 – 1290.000 | 35 / 35 | – | |
| Mercury | 0.065 – 0.567 | 28 / 35 | 0.028 – 0.050 | Below Screening Levels |
| Molybdenum | – | 0 / 3 | 1.490 – 1.490 | Not Detected |
| **Nickel** | 12.200 – 99.200 | 35 / 35 | – | |
| Potassium | 486.000 – 3800.000 | 35 / 35 | – | Below Screening Levels |
| Selenium | – | 0 / 34 | 4.420 – 20.700 | Not Detected |
| Silver | 0.055 – 0.794 | 3 / 35 | 0.034 – 0.803 | Below Screening Levels |
| Sodium | 53.100 – 693.000 | 35 / 35 | – | Below Screening Levels |
| Tellurium | – | 0 / 3 | 5.480 – 5.480 | Not Detected |
| Thallium | – | 0 / 35 | 0.200 – 34.300 | Not Detected |
| Tin | 6.610 – 6.610 | 1 / 10 | 5.390 – 5.810 | Low frequency of detection; within natural levels in the lit. |
| Uranium | 0.151 – 0.151 | 1 / 10 | 0.108 – 0.119 | Low frequency of detection; within natural levels in the lit. |
| Vanadium | 23.700 – 126.767 | 35 / 35 | – | Below Screening Levels |
| **Zinc** | 53.800 – 849.000 | 35 / 35 | – | |
| Cyanide | 0.319 – 0.429 | 3 / 23 | 0.250 – 5.000 | Below Screening Levels |

[a] Chemicals of potential concern are identified in bold.
[b] Includes PAHs with 3 rings or less: acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene.
[c] Includes PAHs with greater than 3 rings: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3–cd)pyrene, pyrene
[d] According to guidance from U.S. EPA Region I, PAHs were grouped into low and high MW categories based on similar modes of action.

COPC – Chemical of potential concern
lit. – Literature
MW – Molecular weight
PAHs – Polychlorinated aromatic hydrocarbons
SL – Screening level

Table A-2

Preliminary Screening Values
for the Northern Short-Tailed Shrew

| Chemical | Screening Values Based on Soil Ingestion (mg/kg) | Screening Values Based on Earthworm Ingestion (mg/kg) |
|---|---|---|
| **Organics** | | |
| Acetone | 9.31E+03 | NC |
| Aldrin | 5.17E-01 | 1.62E-02 |
| Benzene | 1.66E+01 | NC |
| Benzyl alcohol | 8.28E+01 | NC |
| 2-Butanone | 1.81E+04 | NC |
| Butyl benzyl phthalate | 6.21E+01 | NC |
| Chlordane | 1.34E+00 | 2.79E-02 |
| DDD | 2.48E+02 | 3.10E+00 |
| DDE | 4.55E+01 | 6.37E-01 |
| DDT | 1.03E+01 | 1.01E-01 |
| Dieldrin | 3.41E+00 | 3.57E-02 |
| beta-Endosulfan | 8.79E-01 | NC |
| Endrin | 2.59E+00 | 7.44E-02 |
| Heptachlor | 5.17E-01 | NC |
| Heptachlor epoxide | 2.59E+00 | 8.93E-02 |
| gamma-HCCH | 3.41E+00 | 3.49E-02 |
| Isodrin | 4.81E-01 | NC |
| Methoxychlor | 1.24E+02 | 4.59E-01 |
| 2-Methyl naphthalene | 3.47E+02 | NC |
| PAHs | | |
| Low MW [a] | 2.59E+02 | 1.01E+02 |
| High MW [b] | 2.07E+00 | 6.53E-01 |
| PCB (Aroclor 1260) | 7.24E+01 | 3.41E-01 |
| Tetrachloroethene | 1.14E+02 | NC |
| Toluene | 2.28E+02 | NC |
| **Inorganics** | | |
| Aluminum | 8.28E+02 | 2.52E+02 |
| Arsenic | 1.97E+00 | 4.24E+00 |
| Barium | 1.91E+03 | 5.51E+02 |
| Beryllium | 5.69E+00 | NC |
| Boron | 1.81E+02 | NC |
| Cadmium | 1.71E+01 | 3.84E-01 |
| Chromium | 9.31E+00 | 1.25E+00 |
| Cobalt | 5.17E+01 | NC |
| Copper | 2.69E+03 | 6.33E+02 |
| Cyanide | 1.14E+02 | NC |
| Lead | 4.76E+01 | 9.30E+00 |
| Manganese | 2.90E+02 | 2.73E+02 |
| Mercury | 3.26E+02 | 9.25E+01 |
| Nickel | 1.45E+00 | 8.33E-02 |
| Potassium | 3.47E+03 | NC |
| Selenium | 3.88E+00 | NC |
| Silver | 2.07E+02 | NC |
| Sodium | 1.03E+04 | NC |
| Tin | NC | NC |
| Uranium | NC | NC |
| Vanadium | 1.76E+02 | NC |
| Zinc | 1.03E+03 | 1.08E+01 |

## Table A-3

## Model for Calculating Screening Levels for the Northern Short-Tailed Shrew Based on the Incidental Ingestion of Soil

$$\text{Screening Level (SL) for Soil Ingestion (mg/kg)} = \frac{RTV \times BW \times CF}{SIR \times FI}$$

**Where:**

| | | |
|---|---|---|
| SL | = | Screening level based on soil ingestion (mg/kg) |
| RTV | = | Reference toxicity value (mg/kg-day) |
| SIR | = | Soil ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| SL | = | Screening levels are presented in Table A-2 |
| RTV | = | Reference toxicity values are presented in Table A-6 |
| SIR | = | 0.29 g dry weight/day[a] |
| FI | = | 1[b] |
| BW | = | 0.015 kg (EPA, 1993) |
| CF | = | 1000 g/kg |

[a]Assumed to be 10.4% of food intake (EPA, 1993).
[b]Assumes home range of the shrew falls within the site area.

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## Table A-4

## Model for Calculating Screening Levels for the Northern Short-Tailed Shrew Based on the Ingestion of Earthworms

$$\text{Screening Level (SL) for Earthworm Ingestion (mg/kg)} = \frac{RTV \times BW \times CF}{BAF \times IR \times FI}$$

**Where:**

| | | |
|---|---|---|
| SL | = | Screening level based on earthworm ingestion (mg/kg) |
| RTV | = | Reference toxicity value (mg/kg-day) |
| BAF | = | Soil-to-earthworm bioaccumulation factor (unitless) |
| IR | = | Earthworm ingestion rate (g dry weight/day) |
| FI | = | Fraction ingested from contaminated source (unitless) |
| BW | = | Body weight (kg) |
| CF | = | Conversion factor (g/kg) |

**Exposure Assumptions**

| | | |
|---|---|---|
| SL | = | Screening levels are presented in Table A-2 |
| RTV | = | Reference toxicity values are presented in Table A-6 |
| BAF | = | Bioaccumulation factors are presented in Table A-5 |
| IR | = | 2.8 g dry weight/day (EPA, 1993) |
| FI | = | 1[a] |
| BW | = | 0.015 kg (EPA, 1993) |
| CF | = | 1000 g/kg |

[a]Assumes home range of the shrew falls within the site area.

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## Table A-5

## Earthworm Bioaccumulation Factors (BAFs) for Screening the Chemicals of Potential Concern

| Chemical | Bioaccumulation Factor[a] | Reference |
|---|---|---|
| **Organics** | | |
| Acetone | NA | ---- |
| Aldrin | 3.30E+00 | Gish, 1970 |
| Benzene | NA | ---- |
| Benzyl alcohol | NA | ---- |
| 2-Butanone | NA | ---- |
| Butyl benzyl phthalate | NA | ---- |
| Chlordane | 5.00E+00 | Gish, 1970 |
| DDD | 8.30E+00 | Gish, 1970 |
| DDE | 7.40E+00 | Gish, 1970 |
| DDT | 1.06E+01 | Gish, 1970 |
| Dieldrin | 9.90E+00 | Gish, 1970 |
| beta-Endosulfan | NA | ---- |
| Endrin | 3.60E+00 | Gish, 1970 |
| Heptachlor | NA | ---- |
| Heptachlor epoxide | 3.00E+00 | Gish, 1970 |
| gamma-HCCH | 1.01E+01 | Wheatley and Hardman, 1968 |
| Isodrin | NA | ---- |
| Methoxychlor | .280E+01 | Thompson, 1973 |
| 2-Methyl naphthalene | NA | ---- |
| **PAHs** | | |
| Acenaphthene | 3.00E-01 | Beyer and Stafford, 1993 |
| Acenaphthylene | 2.20E-01 | Beyer and Stafford, 1993 |
| Anthracene | 3.20E-01 | Beyer and Stafford, 1993 |
| Benzo(a)anthracene | 2.70E-01 | Beyer and Stafford, 1993 |
| Benzo(a)pyrene | 3.40E-01 | Beyer and Stafford, 1993 |
| Benzo(b)fluoranthene | 2.10E-01 | Beyer and Stafford, 1993 |
| Benzo(g,h,i)perylene | 1.50E-01 | Beyer and Stafford, 1993 |
| Benzo(k)fluoranthene | 2.10E-01 | Beyer and Stafford, 1993 |

## Table A-5

## Earthworm Bioaccumulation Factors (BAFs) for Screening the Chemicals of Potential Concern (Continued)

| Chemical | Bioaccumulation Factor[a] | Reference |
|---|---|---|
| Chrysene | 4.40E-01 | Beyer and Stafford, 1993 |
| Dibenz(a,h)anthracene | 4.90E-01 | Beyer and Stafford, 1993 |
| Fluoranthene | 3.70E-01 | Beyer and Stafford, 1993 |
| Fluorene | 2.00E-01 | Beyer and Stafford, 1993 |
| Indeno(1,2,3-cd)pyrene | 4.10E-01 | Beyer and Stafford, 1993 |
| Phenanthrene | 2.80E-01 | Beyer and Stafford, 1993 |
| Pyrene | 3.90E-01 | Beyer and Stafford, 1993 |
| PCB (Aroclor 1260) | 2.20E+01 | Diercxsens et al., 1985 |
| Tetrachloroethene | NA | ---- |
| Toluene | NA | ---- |
| **Inorganics** | | |
| Aluminum | 3.40E-01 | Beyer and Stafford, 1993 |
| Arsenic | 4.80E-02 | Beyer and Cromartie, 1987 |
| Barium | 3.60E-01 | Beyer and Stafford, 1993 |
| Beryllium | NA | ---- |
| Boron | NA | ---- |
| Cadmium | 4.60E+00 | Beyer and Stafford, 1993 |
| Chromium | 7.70E-01 | Beyer and Cromartie, 1987 |
| Cobalt | NA | ---- |
| Copper | 4.40E-01 | Beyer and Cromartie, 1987 |
| Cyanide | NA | ---- |
| Lead | 5.30E-01 | Beyer and Cromartie, 1987 |
| Manganese | 1.10E-01 | Kabata-Pendias and Pendias, 1984 |
| Mercury | 3.65E-01 | Kabata-Pendias and Pendias, 1984 |
| Nickel | 1.80E+00 | Kabata-Pendias and Pendias, 1984 |
| Potassium | NA | ---- |
| Selenium | NA | ---- |
| Silver | NA | ---- |

## Table A-5

## Earthworm Bioaccumulation Factors (BAFs) for Screening the Chemicals of Potential Concern (Continued)

| Chemical | Bioaccumulation Factor[a] | Reference |
|---|---|---|
| Sodium | NA | ---- |
| Tin | NA | ---- |
| Uranium | NA | ---- |
| Vanadium | NA | ---- |
| Zinc | 9.90E+00 | Beyer and Cromartie, 1987 |

[a]Reported on a dry weight basis.

## Table A-6

### Basis of the Shrew Reference Toxicity Values (RTVs) (mg/kg-day)

| Chemical | Species | Toxicity Endpoint | Effect | Dose (mg/kg-day) | Reference | Applied Safety Factor [c] | Shrew RTVs (mg/kg-day) |
|---|---|---|---|---|---|---|---|
| **Organics** | | | | | | | |
| Acetone | Rat | Chronic NOAEL | No effect on spermatogenesis | 9.00E+02 | Dietz et al., 1991 | 5 | 1.8E+02 |
| Aldrin | Rat | Chronic Effect Dose | Nephritis in females | 2.50E-01 | Reuber, 1980 | 25 | 1.0E-02 |
| Benzene | Mouse | Chronic Effect Dose | Immunotoxic effects/severe anemia | 8.00E+00 | Hsieh et al., 1988 | 25 | 3.2E-01 |
| Benzyl alcohol | Rat | Acute $LD_{50}$ | Mortality | 1.23E+03 | RTECS, 1993 | 750 | 1.6E+00 |
| 2-Butanone | Rat | Chronic NOAEL | No effect on pup survival | 1.77E+03 | Cox et al., 1975 | 5 | 3.5E+02 |
| Butyl benzyl phthalate | Mouse | Acute NOAEL | No maternal or fetotoxicity | 1.82E+02 | NTP, 1990 | 150 | 1.2E+00 |
| Chlordane | Mouse | Chronic NOAEL | No significant liver lesions | 1.30E-01 | Khasawinah and Grutsch, 1989 | 5 | 2.6E-02 |
| DDD | Rat | Chronic Effect Dose | Decreased organ/body weight;suppressed immunity | 1.21E+02 | Hamid et al., 1974 | 25 | 4.8E+00 |
| DDE | Rat | Chronic Effect Dose | Mortality associated with tumor growth | 2.19E+01 | NCI, 1978 | 25 | 8.8E-01 |
| DDT | Rat | Chronic NOAEL | No growth effect on pups | 1.00E+00 | Clement et al., 1974 | 5 | 2.0E-01 |
| Dieldrin | Mouse | Chronic NOAEL | No significant pup mortality | 3.30E-01 | Virgo and Bellward, 1975 | 5 | 6.6E-02 |
| beta-Endosulfan | Rat | Acute NOAEL | No liver enzyme induction | 2.50E+00 | Den Tonkelaar and Van Esch, 1974 | 150 | 1.7E-02 |
| Endrin | Rat | Chronic NOAEL | No significant mortality | 2.50E-01 | Treon et al., 1955 | 5 | 5.0E-02 |
| Heptachlor | Rat | Chronic Effect Dose | 16% embryo survival, decreased fertility | 2.50E-01 | Green, 1970 | 25 | 1.0E-02 |
| Heptachlor epoxide | Rat | Chronic NOAEL | No effects | 2.50E-01 | Dow Chemical Co., 1959 | 5 | 5.0E-02 |
| gamma-HCCH | Rat | Chronic NOAEL | No liver/kidney toxicity | 3.30E-01 | Zoecon Corp., 1983 | 5 | 6.6E-02 |
| Isodrin | Rat | LD50 | Mortality | 7.00E+00 | Sax, 1984 | 750 | 9.3E-03 |
| Methoxychlor | Rat | Chronic Effect Dose | Reduced fertility, late onset of puberty | 6.00E+01 | Harris et al., 1974 | 25 | 2.4E+00 |
| 2-Methyl naphthalene | Rat | LDlo | Mortality | 5.00E+03 | Sax, 1984 | 750 | 6.7E+00 |
| PAHs | | | | | | | |
| Low MW [a] | Mouse | Chronic NOAEL | No decrease in RBC, packed cell vol., or hemoglobin | 1.25E+02 | IRIS, 1995 | 5 | 2.5E+01 |
| High MW [b] | Mouse | Chronic LOAEL | Impaired fertility | 1.00E+01 | Opresko et al., 1994 | 25 | 4.0E-01 |
| PCB (Aroclor 1260) | Rat | Chronic NOAEL | No reproductive effect | 6.90E+00 | Linder et al., 1974 | 5 | 1.4E+00 |
| Tetrachloroethene | Rat | Chronic LOAEL | Decreased BW in females, incr. organ to BW ratio | 5.60E+01 | Hayes et al., 1986 | 25 | 2.2E+00 |
| Toluene | Mouse | Chronic NOAEL | No effect on immune function | 2.20E+01 | Hsieh et al., 1989 | 5 | 4.4E+00 |
| **Inorganics** | | | | | | | |
| Aluminum | Rat (male) | Chronic No Effect Dose | No reproductive abnormalities | 7.75E+01 | Dixon et al., 1979 | 5 | 1.6E+01 |
| Arsenic | Mouse | Chronic Effect Dose | Decreased survival in males | 9.50E-01 | Schroeder and Balassa, 1967 | 25 | 3.8E-02 |
| Barium | Mouse | Chronic NOAEL | No significant mortality or behavioral effects | 1.83E+02 | Dietz et al., 1992 | 5 | 3.7E+01 |
| Beryllium | Rat | Chronic NOAEL | No adverse effects | 5.40E-01 | IRIS, 1995 | 5 | 1.1E-01 |
| Boron | Rat | Chronic NOAEL | No testicular/ovarian effects | 1.75E+01 | Weir and Fisher, 1972 | 5 | 3.5E+00 |
| Cadmium | Rat | Chronic NOAEL | No effect on motor or kidney function | 1.64E+00 | Kotsonis and Klaassen, 1978 | 5 | 3.3E-01 |
| Chromium | Mouse | Chronic Effect Dose | Decreased spermatogenesis | 4.57E+00 | Zahid et al., 1990 | 25 | 1.8E-01 |
| Cobalt | Rat | Chronic NOAEL | No testicular atrophy | 5.00E+00 | Nation et al., 1983 | 5 | 1.0E+00 |
| Copper | Mouse | Chronic NOAEL | No reproductive effects | 2.60E+02 | Lecyk, 1980 | 5 | 5.2E+01 |
| Cyanide | Rat | Chronic NOAEL | No weight loss, thyroid effects, or myelin degener. | 1.08E+01 | Howard and Hanzel, 1955 | 5 | 2.2E+00 |
| Lead | Rat | Chronic NOAEL | No depressed immunity | 4.60E+00 | Luster et al., 1978 | 5 | 9.2E-01 |
| Manganese | Rat | Chronic Effect Dose | Motor ability, aggressive behavior | 1.40E+02 | Chandra, 1983 | 25 | 5.6E+00 |
| Mercury | Rat | Chronic NOAEL | Kidney enlargement | 3.15E+01 | Fitzhugh et al., 1950 | 5 | 6.3E+00 |
| Nickel | Rat | Chronic Effect Dose | Increased number of young deaths and runts | 7.00E-01 | Schroeder and Mitchener, 1971 | 25 | 2.8E-02 |
| Potassium | Rat | Acute NOAEL | No effects | 1.00E+04 | Drescher et al., 1958 | 150 | 6.7E+01 |
| Selenium | Mouse | Chronic NOAEL | No effects on fetal growth | 3.75E-01 | Nobunaga et al., 1979 | 5 | 7.5E-02 |
| Silver | Rat | Chronic No Effect Dose | No effects | 2.00E+01 | Walker, 1971 | 5 | 4.0E+00 |
| Sodium | Rat | Chronic NOAEL | Increased mortality | 1.00E+03 | Meneely and Ball, 1958 | 5 | 2.0E+02 |
| Tin | NDA | --- | --- | --- | --- | --- | --- |
| Uranium | NDA | --- | --- | --- | --- | --- | --- |
| Vanadium | Mouse | Chronic NOAEL | No decreased motility, fertility | 1.68E+01 | Llobet et al., 1993 | 5 | 3.4E+00 |
| Zinc | Rat | Chronic NOAEL | No reproductive effects | 1.00E+02 | Schlicker and Cox, 1968 | 5 | 2.0E+01 |

[a] Based on fluorene
[b] Based on benzo(a)pyrene
[c] See Table A-7

## Table A-7

### Safety Factors Used to Derive Screening Reference Toxicity Values for Terrestrial Target Organisms

| Available Toxicity Endpoint | Target Toxicity Endpoint | Safety Factor |
|---|---|---|
| Acute LOAEL | Acute NOAEL | 5 |
| Acute NOAEL | Chronic NOAEL | 30 * |
| Chronic LOAEL | Chronic NOAEL | 5 |
| Within Phylogenetic Class Sensitivity (i.e., different species but same class) | Target Species Toxicity | 5 |

* From Ford, 1992. This extrapolation from acute to chronic effects is included only to develop RTVs for screening purposes, in order to prevent screening out chemicals for which only acute data are available. However, because of the uncertainty associated with this extrapolation, it was not used to develop RTVs in the risk estimation.

For example, in developing a reference toxicity value for a short-tailed shrew when the only data available is an acute LOAEL for a rat, the following steps would be taken:

Rat acute LOAEL for Compound X = 600 mg/kg.

(1) Acute LOAEL → Acute NOAEL

$$\frac{600\ mg/kg}{5} = 120\ mg/kg$$

(2) Acute NOAEL → Chronic NOAEL

$$\frac{120\ mg/kg}{30} = 4\ mg/kg$$

(3) Within Phylogenetic Class → Target Species Screening RTV

$$\frac{4\ mg/kg}{5} = 0.8\ mg/kg$$

## Table A–8

### Background Concentrations of Metals in U.S. Soils (mg/kg)

| Chemical | Eastern U.S. Soils[a] | | U.S. Various Soils[b] | | New Jersey Soils[c] All areas Arithmetic Mean | New Jersey Soils[c] Urban areas Arithmetic Mean |
|---|---|---|---|---|---|---|
| | Range | Arithmetic Mean | Range | Mean | | |
| Aluminum | 7000 – >100,000 | 57000 | NDA | NDA | NDA | NDA |
| Arsenic | <0.1– 73 | 7.4 | <1– 93.2 | 7 | 5.38 | 8.26 |
| Cadmium | NDA | NDA | 0.41 – 1.5 | NDA | 0.37 | 0.65 |
| Calcium | 100 – 280000 | 6300 | NDA | NDA | NDA | NDA |
| Chromium | 1 – 1000 | 52 | 7 – 1500 | 50 | 12.3 | 12.06 |
| Copper | <1– 700 | 22 | 3 – 300 | 26 | 17.2 | 42.2 |
| Iron | 100 – >100000 | 25000 | 5000 – 50000 | NDA | NDA | NDA |
| Lead | <10– 300 | 17 | <10– 70 | 26 | 58.4 | 177.71 |
| Magnesium | 50 – 50000 | 4600 | NDA | NDA | NDA | NDA |
| Manganese | <2– 7000 | 640 | 20 – 3000 | 490 | 261 | 334 |
| Nickel | <5– 700 | 18 | <5– 150 | 18.5 | 10.3 | 16.56 |
| Tin | <0.1– 10 | 1.5 | <0.1– 7.7 | 0.6 – 1.7 | NDA | NDA |
| Uranium | 0.29 – 11 | 2.7 | 0.3 – 10.7 | 3.7 | NDA | NDA |
| Zinc | <5– 2900 | 52 | 10 – 300 | 73.5 | 73.4 | 127.5 |

NDA – No data available

Sources:

[a] Shacklette and Boerngen, 1984

[b] Kabata–Pendias and Pendias, 1984

[c] NJDEPE, 1992

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# APPENDIX B

# CALCULATION OF CHEMICAL CONCENTRATIONS IN EARTHWORMS

## Appendix B
## Calculation of Chemical Concentrations in Earthworms

Calculation of chemical concentrations in earthworms were determined by multiplying chemical-specific bioaccumulation factors (BAFs) by chemical concentrations found in soils. Accumulation of chemicals in earthworms is dependent on numerous site-specific factors: soil type, pH, soil organic content, and earthworm species. When two or more BAFs were available for a specific chemical, the BAF determined at conditions most similar to those at the site was selected. If experimental soil conditions were unavailable for comparison to known soil conditions, then an average BAF for a given chemical at soil concentrations similar to those found at the site was selected (Beyer and Cromartie, 1987). BAFs were calculated in the experimental studies by dividing the concentration detected in the earthworm by the concentration measured in soil; the ratio is expressed as follows:

$$BAF = \frac{Earthworm\ concentration}{Soil\ concentration}$$

The ingestion rates used for birds and mammals are in dry weight (*i.e.*, grams dry weight diet/day); therefore, BAFs which were calculated based on earthworm and soil wet weight have been converted to dry weight by multiplying wet weight BAFs by 4 (Beyer and Gish, 1980). The chemical-specific BAFs and their sources are presented in Table B-1. The estimated earthworm concentrations are presented in Table B-2.

## Table B-1
## Earthworm Bioaccumulation Factors (BAFs) for the Chemicals of Potential Concern

| Chemical | Bioaccumulation Factor[a] | Reference |
|---|---|---|
| **Organics** | | |
| Chlordane | 5.00E+00 | Gish, 1970 |
| DDD | 8.30E+00 | Gish, 1970 |
| DDE | 7.40E+00 | Gish, 1970 |
| DDT | 1.06E+01 | Gish, 1970 |
| Dieldrin | 9.90E+00 | Gish, 1970 |
| Endrin | 3.60E+00 | Gish, 1970 |
| **PAHs** | | |
| Benzo(a)anthracene | 2.70E-01 | Beyer and Stafford, 1993 |
| Benzo(a)pyrene | 3.40E-01 | Beyer and Stafford, 1993 |
| Benzo(b)fluoranthene | 2.10E-01 | Beyer and Stafford, 1993 |
| Benzo(g,h,i)perylene | 1.50E-01 | Beyer and Stafford, 1993 |
| Benzo(k)fluoranthene | 2.10E-01 | Beyer and Stafford, 1993 |
| Chrysene | 4.40E-01 | Beyer and Stafford, 1993 |
| Dibenz(a,h)anthracene | 4.90E-01 | Beyer and Stafford, 1993 |
| Fluoranthene | 3.70E-01 | Beyer and Stafford, 1993 |
| Indeno(1,2,3-cd)pyrene | 4.10E-01 | Beyer and Stafford, 1993 |
| Pyrene | 3.90E-01 | Beyer and Stafford, 1993 |
| PCB (Aroclor 1260) | 2.20E+01 | Diercxsens et al., 1985 |
| **Inorganics** | | |
| Arsenic | 4.80E-02 | Beyer and Cromartie, 1987 |
| Cadmium | 4.60E+00 | Beyer and Stafford, 1993 |
| Chromium | 7.70E-01 | Beyer and Cromartie, 1987 |
| Copper | 4.40E-01 | Beyer and Cromartie, 1987 |
| Lead | 5.30E-01 | Beyer and Cromartie, 1987 |
| Manganese | 1.10E-01 | Kabata-Pendias and Pendias, 1984 |
| Nickel | 1.80E+00 | Kabata-Pendias and Pendias, 1984 |
| Zinc | 9.90E+00 | Beyer and Cromartie, 1987 |

[a]Reported on a dry weight basis.

## Table B-2

## Estimation of Earthworm Concentrations

| Chemical | Soil Concentration (mg/kg) Mean | Soil Concentration (mg/kg) 95 UCL | BAF [a] | Earthworm Concentration [a] (mg/kg) Mean | Earthworm Concentration [a] (mg/kg) 95 UCL |
|---|---|---|---|---|---|
| **Organics** | | | | | |
| Chlordane | 1.67E+00 | 5.64E+00 | 5.00E+00 | 8.35E+00 | 2.82E+01 |
| DDD | 2.41E−01 | 8.19E−01 | 8.30E+00 | 2.00E+00 | 6.80E+00 |
| DDE | 5.61E−01 | 2.57E+00 | 7.40E+00 | 4.15E+00 | 1.90E+01 |
| DDT | 8.01E−01 | 4.61E+00 | 1.06E+01 | 8.49E+00 | 4.89E+01 |
| Dieldrin | 3.43E−02 | 9.67E−02 | 9.90E+00 | 3.40E−01 | 9.57E−01 |
| Endrin | 2.70E−01 | 5.00E−01 | 3.60E+00 | 9.72E−01 | 1.80E+00 |
| PAHs | | | | | |
| Benzo(a)anthracene | 2.33E+00 | 7.83E+00 | 2.70E−01 | 6.29E−01 | 2.11E+00 |
| Benzo(a)pyrene | 2.62E+00 | 3.63E+00 | 3.40E−01 | 8.91E−01 | 1.23E+00 |
| Benzo(b)fluoranthene | 1.72E+00 | 3.94E+00 | 2.10E−01 | 3.61E−01 | 8.27E−01 |
| Benzo(g,h,i)perylene | 1.53E+00 | 4.44E+00 | 1.50E−01 | 2.30E−01 | 6.66E−01 |
| Benzo(k)fluoranthene | 2.30E+00 | 6.06E+00 | 2.10E−01 | 4.83E−01 | 1.27E+00 |
| Chrysene | 2.36E+00 | 1.31E+01 | 4.40E−01 | 1.04E+00 | 5.76E+00 |
| Dibenz(a,h)anthracene | 3.75E−01 | 4.65E−01 | 4.90E−01 | 1.84E−01 | 2.28E−01 |
| Fluoranthene | 3.57E+00 | 5.55E+00 | 3.70E−01 | 1.32E+00 | 2.05E+00 |
| Indeno(1,2,3−cd)pyrene | 1.87E+00 | 4.09E+00 | 4.10E−01 | 7.67E−01 | 1.68E+00 |
| Pyrene | 4.17E+00 | 7.01E+00 | 3.90E−01 | 1.63E+00 | 2.73E+00 |
| PCB (Aroclor 1260) | 3.15E−01 | 4.96E−01 | 2.20E+01 | 6.93E+00 | 1.09E+01 |
| **Inorganics** | | | | | |
| Arsenic | 1.39E+01 | 1.69E+01 | 4.80E−02 | 6.67E−01 | 8.11E−01 |
| Cadmium | 6.92E−01 | 8.09E−01 | 4.60E+00 | 3.18E+00 | 3.72E+00 |
| Chromium | 2.40E+01 | 2.68E+01 | 7.70E−01 | 1.85E+01 | 2.06E+01 |
| Copper | 1.00E+02 | 1.01E+02 | 4.40E−01 | 4.40E+01 | 4.44E+01 |
| Lead | 2.13E+02 | 2.91E+02 | 5.30E−01 | 1.13E+02 | 1.54E+02 |
| Manganese | 3.90E+02 | 4.41E+02 | 1.10E−01 | 4.29E+01 | 4.85E+01 |
| Nickel | 2.86E+01 | 3.38E+01 | 1.80E+00 | 5.15E+01 | 6.08E+01 |
| Zinc | 1.38E+02 | 1.57E+02 | 9.90E+00 | 1.37E+03 | 1.55E+03 |

[a] Expressed in dry weight



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# APPENDIX C

## CALCULATION OF CHEMICAL CONCENTRATIONS IN SEEDS

## Appendix C
## Calculation of Chemical Concentrations in Seeds

Chemical concentrations in seeds resulting from the uptake of chemicals from the soil were calculated using the following equation:

$$C_{seed} = C_{soil} \times PUF$$

Where:

| | | |
|---|---|---|
| $C_{seed}$ | = | Chemical concentration in seed (mg/kg dry weight seed) |
| $C_{soil}$ | = | Chemical concentration in soil (mg/kg dry weight soil) |
| PUF | = | Plant uptake factor (chemical-specific factor; unitless) |

Plant uptake factors (PUFs) for organics were estimated using the relationship presented by Travis and Arms (1988):

$$PUF = 38.7 \times Kow^{-0.578}$$

Where:

| | | |
|---|---|---|
| PUF | = | Plant uptake factor (chemical-specific; unitless) |
| Kow | = | Octanol-water partition coefficient (chemical-specific) |

For inorganics, transfer coefficients developed by Baes et al. (1984) for reproductive portions of plants were used to calculate concentrations of inorganic chemicals in seeds. These inorganic transfer coefficients are based on one or more of the following: analysis of literature, correlations with other parameters, elemental systematics, and comparisons of predicted with observed elemental concentrations in foods. The PUFs are reported in dry weight. The chemical-specific PUFs, Kows, and their sources are presented in Table C-1. The estimated plant seed concentrations are presented in Table C-2.

## Table C-1
## Plant Uptake Factors for the Chemicals of Potential Concern

| Chemical | Plant Uptake Factor[a] | Log Kow | Reference |
|---|---|---|---|
| **Organics** | | | |
| Chlordane | 9.57E-01 | 2.78 | EPA, 1987c |
| DDD | 1.34E-02 | 5.99 | EPA, 1992c |
| DDE | 2.16E-02 | 5.63 | EPA, 1987c |
| DDT | 5.77E-02 | 4.89 | EPA, 1987c |
| Dieldrin | 3.48E-01 | 3.54 | EPA, 1987c |
| Endrin | 3.48E-01 | 3.54 | EPA, 1987c |
| **PAHs** | | | |
| Benzo(a)anthracene | 2.21E-02 | 5.61 | EPA, 1987c |
| Benzo(a)pyrene | 1.77E-01 | 4.05 | EPA, 1987c |
| Benzo(b)fluoranthene | 1.22E-02 | 6.06 | EPA, 1987c |
| Benzo(g,h,i)perylene | 6.68E-03 | 6.51 | EPA, 1987c |
| Benzo(k)fluoranthene | 1.22E-02 | 6.06 | EPA, 1987c |
| Chrysene | 2.21E-02 | 5.61 | EPA, 1987c |
| Dibenz(a,h)anthracene | 1.37E-02 | 5.97 | EPA, 1987c |
| Fluoranthene | 5.70E-02 | 4.90 | EPA, 1987c |
| Indeno(1,2,3-cd)pyrene | 6.68E-03 | 6.51 | EPA, 1987c |
| Pyrene | 5.85E-02 | 4.88 | EPA, 1987c |
| PCB (Aroclor 1260) | 1.14E-02 | 6.11 | EPA, 1987c |
| **Inorganics** | | | |
| Arsenic | 6.00E-03 | NA | Baes et al., 1984 |
| Cadmium | 1.50E-01 | NA | Baes et al., 1984 |
| Chromium | 4.50E-03 | NA | Baes et al., 1984 |
| Copper | 2.50E-01 | NA | Baes et al., 1984 |
| Lead | 9.00E-03 | NA | Baes et al., 1984 |
| Manganese | 5.00E-02 | NA | Baes et al., 1984 |
| Nickel | 6.00E-02 | NA | Baes et al., 1984 |
| Zinc | 9.00E-01 | NA | Baes et. al., 1984 |

[a]Reported on a dry weight basis.
NA - Not applicable

## Table C-2

## Estimation of Seed Concentrations

| Chemical | Soil Concentration (mg/kg) Mean | Soil Concentration (mg/kg) 95 UCL | PUF [a] | Seed Concentration [a] (mg/kg) Mean | Seed Concentration [a] (mg/kg) 95 UCL |
|---|---|---|---|---|---|
| **Organics** | | | | | |
| Chlordane | 1.67E+00 | 5.64E+00 | 9.57E−01 | 1.60E+00 | 5.40E+00 |
| DDD | 2.41E−01 | 8.19E−01 | 1.34E−02 | 3.23E−03 | 1.10E−02 |
| DDE | 5.61E−01 | 2.57E+00 | 2.16E−02 | 1.21E−02 | 5.55E−02 |
| DDT | 8.01E−01 | 4.61E+00 | 5.77E−02 | 4.62E−02 | 2.66E−01 |
| Dieldrin | 3.43E−02 | 9.67E−02 | 3.48E−01 | 1.19E−02 | 3.37E−02 |
| Endrin | 2.70E−01 | 5.00E−01 | 3.48E−01 | 9.40E−02 | 1.74E−01 |
| PAHs | | | | | |
| Benzo(a)anthracene | 2.33E+00 | 7.83E+00 | 2.21E−02 | 5.15E−02 | 1.73E−01 |
| Benzo(a)pyrene | 2.62E+00 | 3.63E+00 | 1.77E−01 | 4.64E−01 | 6.43E−01 |
| Benzo(b)fluoranthene | 1.72E+00 | 3.94E+00 | 1.22E−02 | 2.10E−02 | 4.81E−02 |
| Benzo(g,h,i)perylene | 1.53E+00 | 4.44E+00 | 6.68E−03 | 1.02E−02 | 2.97E−02 |
| Benzo(k)fluoranthene | 2.30E+00 | 6.06E+00 | 1.22E−02 | 2.81E−02 | 7.39E−02 |
| Chrysene | 2.36E+00 | 1.31E+01 | 2.21E−02 | 5.22E−02 | 2.90E−01 |
| Dibenz(a,h)anthracene | 3.75E−01 | 4.65E−01 | 1.37E−02 | 5.14E−03 | 6.37E−03 |
| Fluoranthene | 3.57E+00 | 5.55E+00 | 5.70E−02 | 2.03E−01 | 3.16E−01 |
| Indeno(1,2,3−cd)pyrene | 1.87E+00 | 4.09E+00 | 6.68E−03 | 1.25E−02 | 2.73E−02 |
| Pyrene | 4.17E+00 | 7.01E+00 | 5.85E−02 | 2.44E−01 | 4.10E−01 |
| PCB (Aroclor 1260) | 3.15E−01 | 4.96E−01 | 1.14E−02 | 3.59E−03 | 5.65E−03 |
| **Inorganics** | | | | | |
| Arsenic | 1.39E+01 | 1.69E+01 | 6.00E−03 | 8.34E−02 | 1.01E−01 |
| Cadmium | 6.92E−01 | 8.09E−01 | 1.50E−01 | 1.04E−01 | 1.21E−01 |
| Chromium | 2.40E+01 | 2.68E+01 | 4.50E−03 | 1.08E−01 | 1.21E−01 |
| Copper | 1.00E+02 | 1.01E+02 | 2.50E−01 | 2.50E+01 | 2.53E+01 |
| Lead | 2.13E+02 | 2.91E+02 | 9.00E−03 | 1.92E+00 | 2.62E+00 |
| Manganese | 3.90E+02 | 4.41E+02 | 5.00E−02 | 1.95E+01 | 2.21E+01 |
| Nickel | 2.86E+01 | 3.38E+01 | 6.00E−02 | 1.72E+00 | 2.03E+00 |
| Zinc | 1.38E+02 | 1.57E+02 | 9.00E−01 | 1.24E+02 | 1.41E+02 |

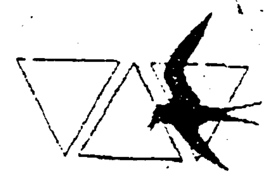
[a] Expressed in dry weight

# APPENDIX D

# BIRD SURVEY FOR THE AMTL SITE VICINITY

MASSACHUSETTS AUDUBON SOCIETY, LINCOLN, MASS. 01773

# a checklist of MASSACHUSETTS BIRDS



Observed by Robert H. Stymeist
94 Grove St. Watertown MA 02172
Total Number of Birds Checked ____ Year ____
617 926-3603 (617) 923-3139

WATERTOWN MASS

ARSENAL PROPERTY * = BREEDING M = MIGRANT - SPRING/FALL

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Red-throated Loon | | | Green-winged Teal | | |
| Common Loon | | | American Black Duck | UNCOMMON | |
| Pied-billed Grebe | Winter visitor - esp. when ponds frozen | | Mallard * | VERY COMMON - BREEDER | |
| Horned Grebe | | | Northern Pintail | | |
| Red-necked Grebe | | | Blue-winged Teal | | |
| Northern Fulmar | | | Northern Shoveler | | |
| Cory's Shearwater | | | Gadwall | | |
| Greater Shearwater | | | Eurasian Wigeon | | |
| Sooty Shearwater | | | American Wigeon | | |
| Manx Shearwater | | | Canvasback | | |
| Wilson's Storm-Petrel | | | Redhead | | |
| Leach's Storm-Petrel | | | Ring-necked Duck | UNCOMMON IN WINTER | |
| Northern Gannet | | | Greater Scaup | | |
| Great Cormorant | | | Lesser Scaup | | |
| Double-crested Cormorant | COMMON APRIL - OCT | | Common Eider | | |
| American Bittern | | | King Eider | | |
| Least Bittern | | | Harlequin Duck | | |
| Great Blue Heron | UNCOMMON THROUGHOUT | | Oldsquaw | | |
| Great Egret | | | Black Scoter | | |
| Snowy Egret | | | Surf Scoter | | |
| Little Blue Heron | | | White-winged Scoter | | |
| Tricolored Heron | | | Common Goldeneye | | |
| Cattle Egret | | | Barrow's Goldeneye | | |
| Green-backed Heron | UNCOMMON MAY-SEPT | | Bufflehead | UNCOMMON IN WINTER | |
| Black-crowned Night-Heron | VERY COMMON LATE MAY-JULY | | Hooded Merganser | COMMON FROM OCT-FEB | |
| Yellow-crowned Night-Heron | | | Common Merganser | COMMON ✓ ✓ ✓ | |
| Glossy Ibis | | | Red-breasted Merganser | UNCOMMON TO RARE WINTER | |
| Mute Swan | | | Ruddy Duck | | |
| Snow Goose | | | Turkey Vulture | | |
| Brant | | | Osprey SPRING + FALL | SEEN ONLY A FEW TIMES | |
| Canada Goose * | BREEDER | | Bald Eagle | | |
| Wood Duck | UNCOMMON IN WINTER | | Northern Harrier | | |

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Sharp-shinned Hawk | OCCASIONAL FALL WINTER | | Baird's Sandpiper | | |
| Cooper's Hawk | RARE | | Pectoral Sandpiper | | |
| Northern Goshawk | | | Purple Sandpiper | | |
| Red-shouldered Hawk | | | Dunlin | | |
| Broad-winged Hawk | | | Stilt Sandpiper | | |
| Red-tailed Hawk | FAIRLY COMMON THR. | | Buff-breasted Sandpiper | | |
| Rough-legged Hawk | | | Ruff | | |
| American Kestrel | OCCASIONAL-ESP WINTER | | Short-billed Dowitcher | | |
| Merlin | | | Long-billed Dowitcher | | |
| Peregrine Falcon | | | Common Snipe | | |
| Ring-necked Pheasant | | | American Woodcock | | |
| Ruffed Grouse | | | Wilson's Phalarope | | |
| Wild Turkey | | | Red-necked Phalarope | | |
| Northern Bobwhite | | | Red Phalarope | | |
| Clapper Rail | | | Pomarine Jaeger | | |
| King Rail | | | Parasitic Jaeger | | |
| Virginia Rail | | | Laughing Gull | | |
| Sora | | | Little Gull | | |
| Common Moorhen | | | Common Black-headed Gull | | |
| American Coot | UNCOMMON IN WINTER | | Bonaparte's Gull | | |
| Black-bellied Plover | | | Ring-billed Gull | COMMON THR. | |
| Lesser Golden-Plover | | | Herring Gull | COMMON THR | |
| Semipalmated Plover | | | Iceland Gull | | |
| Piping Plover | | | Lesser Black-backed Gull | | |
| Killdeer | | | Glaucous Gull | | |
| American Oystercatcher | | | Great Black-backed Gull | COMMON THR | |
| Greater Yellowlegs | | | Black-legged Kittiwake | | |
| Lesser Yellowlegs | | | Caspian Tern | | |
| Solitary Sandpiper | | | Royal Tern | | |
| Willet | | | Roseate Tern | | |
| Spotted Sandpiper | UNCOMMON MAY-SEPT | | Common Tern | | |
| Upland Sandpiper | | | Arctic Tern | | |
| Whimbrel | | | Forster's Tern | | |
| Hudsonian Godwit | | | Least Tern | | |
| Marbled Godwit | | | Black Tern | | |
| Ruddy Turnstone | | | Black Skimmer | | |
| Red Knot | | | Dovekie | | |
| Sanderling | | | Thick-billed Murre | | |
| Semipalmated Sandpiper | | | Razorbill | | |
| Western Sandpiper | | | Black Guillemot | | |
| Least Sandpiper | | | Rock Dove * | VERY COMMON THR | BREEDER |
| White-rumped Sandpiper | | | Mourning Dove * | COMMON THR | ✓ |

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Black-billed Cuckoo | | | American Crow * | COMMON BREEDER | |
| Yellow-billed Cuckoo | | | Fish Crow * | UNCOMMON BREEDER | |
| Common Barn-Owl | | | Black-capped Chickadee * | COMMON BREEDER | |
| Eastern Screech-Owl | OCCASIONAL | | Boreal Chickadee | | |
| Great Horned Owl | | | Tufted Titmouse * | UNCOMMON BREEDER | |
| Snowy Owl | | | Red-breasted Nuthatch | UNCOMMON THR | |
| Barred Owl | | | White-breasted Nuthatch * | UNCOMMON THR | |
| Long-eared Owl | | | Brown Creeper | UNCOMMON WINTER | |
| Short-eared Owl | | | Carolina Wren | | |
| Northern Saw-whet Owl | | | House Wren * | UNCOMMON MAY-SEPT | |
| Common Nighthawk | UNCOMMON FALL MIGRANT | | Winter Wren | | |
| Chuck-will's-widow | | | Sedge Wren | | |
| Whip-poor-will | | | Marsh Wren | | |
| Chimney Swift Breeder * | FAIRLY COMMON MAY-SEPT | | Golden-crowned Kinglet | UNCOMMON WINTER | |
| Ruby-throated Hummingbird | | | Ruby-crowned Kinglet | MIGRANT | |
| Belted Kingfisher * | UNCOMMON THROUGHOUT | | Blue-gray Gnatcatcher | M | |
| Red-headed Woodpecker | | | Eastern Bluebird | | |
| Red-bellied Woodpecker | | | Veery | | |
| Yellow-bellied Sapsucker | | | Gray-cheeked Thrush | | |
| Downy Woodpecker * | COMMON THR- | BREEDER | Swainson's Thrush | M | |
| Hairy Woodpecker | UNCOMMON | | Hermit Thrush | M | |
| Northern Flicker * | FAIRLY COMMON, BREEDER | | Wood Thrush | M | |
| Pileated Woodpecker | | | American Robin * | COMMON BREEDER | |
| Olive-sided Flycatcher | | | Gray Catbird * | COMMON BREEDER | |
| Eastern Wood-Pewee | | | Northern Mockingbird * | COMMON BREEDER | |
| Yellow-bellied Flycatcher | | | Brown Thrasher | M | |
| Acadian Flycatcher | | | Water Pipit | | |
| Alder Flycatcher | | | Cedar Waxwing * | UNCOMMON BREEDER | |
| Willow Flycatcher | | | Northern Shrike | | |
| Least Flycatcher | | | Loggerhead Shrike | | |
| Eastern Phoebe * | UNCOMMON BREEDER | | European Starling * | VERY COMMON BREEDER | |
| Great Crested Flycatcher | | | White-eyed Vireo | | |
| Western Kingbird | | | Solitary Vireo | MIGRANT | |
| Eastern Kingbird * | UNCOMMON BREEDER | | Yellow-throated Vireo | | |
| Horned Lark | | | Warbling Vireo * | FAIRLY COMMON BREEDER | |
| Purple Martin | | | Philadelphia Vireo | | |
| Tree Swallow | UNCOMMON MAY-SEPT | | Red-eyed Vireo | MIGRANT | |
| N. Rough-winged Swallow * | UNCOMMON BREEDER | | Blue-winged Warbler | | |
| Bank Swallow | | | Golden-winged Warbler | | |
| Cliff Swallow | | | Tennessee Warbler | | |
| Barn Swallow | UNCOMMON MAY-SEPT | | Orange-crowned Warbler | | |
| Blue Jay * | COMMON THR- | BREED | Nashville Warbler | M | |

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Northern Parula | M | | Chipping Sparrow * | UNCOMMON BREEDER | |
| Yellow Warbler * | COMMON BREEDER | MAY-AUG | Field Sparrow | | |
| Chestnut-sided Warbler | M | | Vesper Sparrow | | |
| Magnolia Warbler | M | | Lark Sparrow | | |
| Cape May Warbler | | | Savannah Sparrow | | |
| Black-throated Blue Warbler | M | | Grasshopper Sparrow | | |
| Yellow-rumped Warbler | M | | Sharp-tailed Sparrow | | |
| Black-throated Green Warbler | M | | Seaside Sparrow | | |
| Blackburnian Warbler | M | | Fox Sparrow | | |
| Pine Warbler | | | Song Sparrow * | COMMON BREEDER | |
| Prairie Warbler | | | Lincoln's Sparrow | | |
| Palm Warbler | | | Swamp Sparrow | | |
| Bay-breasted Warbler | | | White-throated Sparrow | UNCOMMON OCT-MAY | |
| Blackpoll Warbler | M | | White-crowned Sparrow | | |
| Black-and-white Warbler | M | | Dark-eyed Junco | FAIRLY COMMON OCT-APR | |
| American Redstart | M | | Lapland Longspur | | |
| Worm-eating Warbler | | | Snow Bunting | | |
| Ovenbird | M | | Bobolink | | |
| Northern Waterthrush | M | | Red-winged Blackbird * | UNCOMMON BREEDER | |
| Louisiana Waterthrush | | | Eastern Meadowlark | | |
| Connecticut Warbler | | | Rusty Blackbird | | |
| Mourning Warbler | | | Common Grackle * | UNCOMMON BREEDER | |
| Common Yellowthroat * | UNCOMMON BREEDER | | Brown-headed Cowbird | FAIRLY COMMON APR-SEPT | |
| Hooded Warbler | | | Orchard Oriole | M | |
| Wilson's Warbler | M | | Northern Oriole * | UNCOMMON BREEDER | |
| Canada Warbler | M | | Pine Grosbeak | | |
| Yellow-breasted Chat | | | Purple Finch | | |
| Scarlet Tanager | M | | House Finch * | COMMON BREEDER | |
| Northern Cardinal * | COMMON BREEDER | | Red Crossbill | | |
| Rose-breasted Grosbeak | | | White-winged Crossbill | | |
| Blue Grosbeak | | | Common Redpoll | | |
| Indigo Bunting | | | Pine Siskin | | |
| Dickcissel | | | American Goldfinch * | UNCOMMON BREEDER | |
| Rufous-sided Towhee | M | | Evening Grosbeak | | |
| American Tree Sparrow | UNCOMMON OCT-MAR | | House Sparrow * | COMMON BREEDER | |

* 35 species have been known to breed

* MIGRANTS #s could be more based on more frequent observations

The sequence of species and name changes follow the major revision published in the Vol. 99 No. 3 July 1982

MASSACHUSETTS AUDUBON SOCIETY, LINCOLN, MASS. 01773

# a checklist of MASSACHUSETTS BIRDS

Observed by Birds that could breed in Watertown, MA

Total Number of Birds Checked ______________ Year ________

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Red-throated Loon | | | Green-winged Teal | | |
| Common Loon | | | American Black Duck | | |
| Pied-billed Grebe | | | Mallard | ✓ | |
| Horned Grebe | | | Northern Pintail | | |
| Red-necked Grebe | | | Blue-winged Teal | | |
| Northern Fulmar | | | Northern Shoveler | | |
| Cory's Shearwater | | | Gadwall | | |
| Greater Shearwater | | | Eurasian Wigeon | | |
| Sooty Shearwater | | | American Wigeon | | |
| Manx Shearwater | | | Canvasback | | |
| Wilson's Storm-Petrel | | | Redhead | | |
| Leach's Storm-Petrel | | | Ring-necked Duck | | |
| Northern Gannet | | | Greater Scaup | | |
| Great Cormorant | | | Lesser Scaup | | |
| Double-crested Cormorant | | | Common Eider | | |
| American Bittern | | | King Eider | | |
| Least Bittern | | | Harlequin Duck | | |
| Great Blue Heron | | | Oldsquaw | | |
| Great Egret | | | Black Scoter | | |
| Snowy Egret | | | Surf Scoter | | |
| Little Blue Heron | | | White-winged Scoter | | |
| Tricolored Heron | | | Common Goldeneye | | |
| Cattle Egret | | | Barrow's Goldeneye | | |
| Green-backed Heron | | | Bufflehead | | |
| Black-crowned Night-Heron | ✓ | | Hooded Merganser | | |
| Yellow-crowned Night-Heron | | | Common Merganser | | |
| Glossy Ibis | | | Red-breasted Merganser | | |
| Mute Swan | | | Ruddy Duck | | |
| Snow Goose | | | Turkey Vulture | | |
| Brant | | | Osprey | | |
| Canada Goose | ✓ | | Bald Eagle | | |
| Wood Duck | ✓ | | Northern Harrier | | |

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Sharp-shinned Hawk | | | White-rumped Sandpiper | | |
| Cooper's Hawk | | | Baird's Sandpiper | | |
| Northern Goshawk | | | Pectoral Sandpiper | | |
| Red-shouldered Hawk | | | Purple Sandpiper | | |
| Broad-winged Hawk | | | Dunlin | | |
| Red-tailed Hawk | ✓ | | Stilt Sandpiper | | |
| Rough-legged Hawk | | | Buff-breasted Sandpiper | | |
| Golden Eagle | | | Ruff | | |
| American Kestrel | ✓ | | Short-billed Dowitcher | | |
| Merlin | | | Long-billed Dowitcher | | |
| Peregrine Falcon | | | Common Snipe | | |
| Ring-necked Pheasant | | | American Woodcock | | |
| Ruffed Grouse | | | Wilson's Phalarope | | |
| Wild Turkey | | | Red-necked Phalarope | | |
| Northern Bobwhite | | | Red Phalarope | | |
| Clapper Rail | | | Pomarine Jaeger | | |
| King Rail | | | Parasitic Jaeger | | |
| Virginia Rail | | | Laughing Gull | | |
| Sora | | | Little Gull | | |
| Common Moorhen | | | Common Black-headed Gull | | |
| American Coot | | | Bonaparte's Gull | | |
| Black-bellied Plover | | | Ring-billed Gull | | |
| Lesser Golden-Plover | | | Herring Gull | | |
| Semipalmated Plover | | | Iceland Gull | | |
| Piping Plover | | | Lesser Black-backed Gull | | |
| Killdeer | ✓ | | Glaucous Gull | | |
| American Oystercatcher | | | Great Black-backed Gull | | |
| Greater Yellowlegs | | | Black-legged Kittiwake | | |
| Lesser Yellowlegs | | | Caspian Tern | | |
| Solitary Sandpiper | | | Royal Tern | | |
| Willet | | | Roseate Tern | | |
| Spotted Sandpiper | | | Common Tern | | |
| Upland Sandpiper | | | Arctic Tern | | |
| Whimbrel | | | Forster's Tern | | |
| Hudsonian Godwit | | | Least Tern | | |
| Marbled Godwit | | | Black Tern | | |
| Ruddy Turnstone | | | Black Skimmer | | |
| Red Knot | | | Dovekie | | |
| Sanderling | | | Thick-billed Murre | | |
| Semipalmated Sandpiper | | | Razorbill | | |
| Western Sandpiper | | | Black Guillemot | | |
| Least Sandpiper | | | Rock Dove | ✓ | |

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Mourning Dove | ✓ | | Blue Jay | ✓ | |
| Black-billed Cuckoo | | | American Crow | ✓ | |
| Yellow-billed Cuckoo | | | Fish Crow | | |
| Common Barn-Owl | | | Common Raven | | |
| Eastern Screech-Owl | ✓ | | Black-capped Chickadee | ✓ | |
| Great Horned Owl | ✓ | | Boreal Chickadee | | |
| Snowy Owl | | | Tufted Titmouse | ✓ | |
| Barred Owl | ✓ | | Red-breasted Nuthatch | | |
| Long-eared Owl | | | White-breasted Nuthatch | ✓ | |
| Short-eared Owl | | | Brown Creeper | | |
| Northern Saw-whet Owl | | | Carolina Wren | | |
| Common Nighthawk | ✓ | | House Wren | | |
| Chuck-will's-widow | | | Winter Wren | | |
| Whip-poor-will | | | Sedge Wren | | |
| Chimney Swift | ✓ | | Marsh Wren | | |
| Ruby-throated Hummingbird | | | Golden-crowned Kinglet | | |
| Belted Kingfisher | | | Ruby-crowned Kinglet | | |
| Red-headed Woodpecker | | | Blue-gray Gnatcatcher | | |
| Red-bellied Woodpecker | | | Eastern Bluebird | | |
| Yellow-bellied Sapsucker | | | Veery | | |
| Downy Woodpecker | ✓ | | Gray-cheeked Thrush | | |
| Hairy Woodpecker | ✓ | | Swainson's Thrush | | |
| Northern Flicker | ✓ | | Hermit Thrush | | |
| Pileated Woodpecker | | | Wood Thrush | | |
| Olive-sided Flycatcher | | | American Robin | ✓ | |
| Eastern Wood-Pewee | ✓ | | Gray Catbird | ✓ | |
| Yellow-bellied Flycatcher | | | Northern Mockingbird | ✓ | |
| Acadian Flycatcher | | | Brown Thrasher | | |
| Alder Flycatcher | | | Water Pipit | | |
| Willow Flycatcher | | | Cedar Waxwing | | |
| Least Flycatcher | | | Northern Shrike | | |
| Eastern Phoebe | ✓ | | Loggerhead Shrike | | |
| Great Crested Flycatcher | | | European Starling | ✓ | |
| Western Kingbird | | | White-eyed Vireo | | |
| Eastern Kingbird | ✓ | | Solitary Vireo | | |
| Horned Lark | | | Yellow-throated Vireo | | |
| Purple Martin | | | Warbling Vireo | | |
| Tree Swallow | ✓ | | Philadelphia Vireo | | |
| N. Rough-winged Swallow | | | Red-eyed Vireo | | |
| Bank Swallow | | | Blue-winged Warbler | | |
| Cliff Swallow | | | Golden-winged Warbler | | |
| Barn Swallow | | | Tennessee Warbler | | |

| Name of Species | Locality | Date Seen | Name of Species | Locality | Date Seen |
|---|---|---|---|---|---|
| Orange-crowned Warbler | | | American Tree Sparrow | | |
| Nashville Warbler | | | Chipping Sparrow | | |
| Northern Parula | | | Field Sparrow | | |
| Yellow Warbler | ✓ | | Vesper Sparrow | | |
| Chestnut-sided Warbler | | | Lark Sparrow | | |
| Magnolia Warbler | | | Savannah Sparrow | | |
| Cape May Warbler | | | Grasshopper Sparrow | | |
| Black-throated Blue Warbler | | | Sharp-tailed Sparrow | | |
| Yellow-rumped Warbler | ✓ | | Seaside Sparrow | | |
| Black-throated Green Warbler | | | Fox Sparrow | | |
| Blackburnian Warbler | | | Song Sparrow | ✓ | |
| Pine Warbler | | | Lincoln's Sparrow | | |
| Prairie Warbler | | | Swamp Sparrow | | |
| Palm Warbler | | | White-throated Sparrow | | |
| Bay-breasted Warbler | | | White-crowned Sparrow | | |
| Blackpoll Warbler | | | Dark-eyed Junco | | |
| Black-and-white Warbler | | | Lapland Longspur | | |
| American Redstart | | | Snow Bunting | | |
| Worm-eating Warbler | | | Bobolink | | |
| Ovenbird | | | Red-winged Blackbird | ✓ | |
| Northern Waterthrush | | | Eastern Meadowlark | | |
| Louisiana Waterthrush | | | Rusty Blackbird | | |
| Connecticut Warbler | | | Common Grackle | ✓ | |
| Mourning Warbler | | | Brown-headed Cowbird | ✓ | |
| Common Yellowthroat | ✓ | | Orchard Oriole | | |
| Hooded Warbler | | | Northern Oriole | ✓ | |
| Wilson's Warbler | | | Pine Grosbeak | | |
| Canada Warbler | | | Purple Finch | | |
| Yellow-breasted Chat | | | House Finch | ✓ | |
| Scarlet Tanager | | | Red Crossbill | | |
| Northern Cardinal | ✓ | | White-winged Crossbill | | |
| Rose-breasted Grosbeak | | | Common Redpoll | | |
| Blue Grosbeak | | | Pine Siskin | | |
| Indigo Bunting | | | American Goldfinch | ✓ | |
| Dickcissel | | | Evening Grosbeak | | |
| Rufous-sided Towhee | | | House Sparrow | ✓ | |

The name changes and sequence of species follow the A.O.U. Checklist of North American Birds, 6th edition, 1983.

revised 12/86